Medals of Creation

OR,

FIRST LESSONS IN GEOLOGY,

AND

THE STUDY OF ORGANIC REMAINS.

BY

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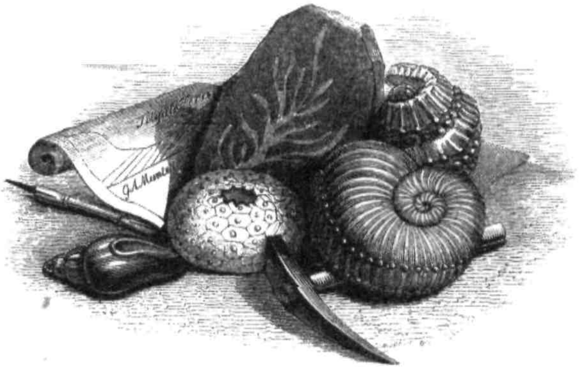

"Voilà! une nouvelle espèce de médailles, beaucoup plus importantes, et incomparablement plus anciennes, que toutes celles des Grecs et des Romains!"—KNORR, *Monumens des Catastrophes.*

IN TWO VOLS.—VOL. I.

CONTAINING

Fossil Vegetables, Zoophytes, Echinoderms, and Molluscs.

SECOND EDITION, ENTIRELY REWRITTEN.

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TO

MY SONS,

WALTER MANTELL,

OF WELLINGTON, NEW ZEALAND,

AND

REGINALD NEVILLE MANTELL,

OF KENTUCKY, UNITED STATES,

This Work,

MY LAST ATTEMPT TO PROMOTE THE ADVANCEMENT

OF SCIENTIFIC KNOWLEDGE,

IS MOST AFFECTIONATELY INSCRIBED.

G. A. M.

Chester Square, Pimlico,
Feb. 3, 1853.

[The above having been penned by the much-lamented author of the "Medals" some months previous to his decease, it is retained in this posthumous edition of his favourite work as an appropriate dedication, dictated by the parental affection of one of the chief promoters of geological science in England, and addressed to his absent sons, whose works have already shown them to be enthusiastic labourers in the same field, both at home and in distant parts of the world.]

PREFATORY NOTE TO THE SECOND EDITION.

THE untimely Decease of the lamented AUTHOR of the "MEDALS OF CREATION" during the progress of the present edition through the press has unavoidably delayed its publication.

The First Volume has been wholly rewritten by the Author.

The materials of the Second Volume had been elaborately revised and much enlarged by DR. MANTELL previously to his Decease. The EDITOR has laboured to carry out the intentions of the Author in rendering this part of the Work as complete a compendium as possible of the Palæontological history of the Organic Beings of which it treats, and in adapting it to the requirements of the Geological Student of the present time.

The various sources from which palæontological and zoological information has been derived have, for the most part, been adverted to in the text or in the foot-

notes. The EDITOR, however, has especially to acknowledge the kindness of MR. J. MORRIS, F.G.S., in allowing him to refer to the proof-sheets of the forthcoming edition of his "Catalogue of British Fossils," and thereby affording him important assistance in making correct statements of the distribution of the Fossil Remains of the CRUSTACEA, INSECTA, and VERTEBRATA, in the strata of the BRITISH ISLANDS.

T. RUPERT JONES.

PREFACE TO THE FIRST EDITION.

In the first edition of the Wonders of Geology, an intention was expressed of immediately publishing, as a sequel to those volumes, "First Lessons," or an Introduction to the Study of Petrifactions, for persons wholly unacquainted with the nature of Fossil Remains; but the completion of the contemplated work was unavoidably postponed, from year to year, by the long and severe indisposition of the Author.

In the meanwhile several works professing the same object have issued from the press; and an enlarged edition of Sir C. Lyell's "Elements" has also appeared, in which the elementary principles of physical Geology are fully illustrated, and numerous figures given of the characteristic fossils of the several formations, or groups of strata. But that department of the science which especially treats of Organic Remains is necessarily considered in a cursory manner; and a work upon the plan originally contemplated by the Author seems still to be required, to initiate the young and uninstructed in the study of those Medals of Creation—those electrotypes of nature—the mineralized remains of the plants and animals which successively flourished in the earlier ages of our planet, in periods incalculably remote, and long antecedent to all human history and tradition.

With this conviction the present volumes are offered, with such modifications of the original plan as circumstances have rendered necessary, as a guide for the Student and the Amateur Collector of fossil remains; for the intelligent Observer who may desire to possess a general knowledge of the subject, without intending to pursue Geology as a science; and for the Tourist who may wish, in the course of his travels, to employ profitably a leisure hour in quest of those interesting memorials of the ancient physical revolutions of our globe, which he will find everywhere presented to his observation.

CRESCENT LODGE,
CLAPHAM COMMON,
May, 1844.

ADDRESS TO THE READER.

"Some books are to be tasted—others to be swallowed—and some few to be chewed and digested; that is, some Books are to be read only in parts—others to be read, but not curiously—and some few to be read wholly and with diligence and attention."—LORD BACON'S ESSAYS.

ANXIOUS that the "COURTEOUS READER" should derive from this work all the information it is designed to impart, the Author presumes to offer a few words in explanation of the plan upon which it has been constructed, and some suggestions as to the best means of rendering its contents most available to the varied tastes and pursuits of different classes of readers.

In its arrangement, a three-fold object was had in view; namely, in the first place, to present such an epitome of PALÆONTOLOGY, the science which treats of the fossil remains of the ancient inhabitants of the Globe, as shall enable the intelligent Observer to comprehend the nature of the principal discoveries in modern Geology, and the method of investigation by which such highly interesting, and unexpected results, have been obtained.

Secondly, to assist the COLLECTOR in his search for Organic Remains,—directing attention to those objects which possess the highest interest, and are especially deserving of accurate examination—instructing him in the art of developing and

preserving the specimens he may discover—and pointing out the means to be pursued, for ascertaining their nature, and their relation to existing plants or animals.

Thirdly, to place before the STUDENT a familiar exposition of the elementary principles of Palæontology, based upon a general knowledge of the structure of vegetable and animal organization; to excite in his mind a desire for further information, and prepare him for the perusal and study of works of a higher order than these unpretending volumes; and to point out the sources from which the required instruction may be derived.

Although fully aware of the imperfect manner in which these intentions are fulfilled, the Author hopes that the indulgence claimed by one of the most able writers of our times may be extended to him; and that, "if the design be good upon the whole, the work will not be censured too severely for those faults, from which, in parts, its very nature would scarcely allow it to be free." *

With regard to the best means of making use of these volumes, the advice of the great founder of Inductive Philosophy, on the Study of Books in general, expressed in the quotation prefixed to this address, is peculiarly applicable to the different classes of readers for whom the work is designed.

Thus, *"the Book may be tasted, that is, read only in parts,"* by the intelligent reader, who requires but a general acquaintance with the subjects it embraces. The perusal of the introductory and concluding remarks of each chapter, of the

* Sir E. B. Lytton—preface to the second edition of "THE DISOWNED."

general descriptions of fossil remains, and of the circumstances under which they occur,—omitting the scientific terms and descriptions,—and a cursory examination of the illustrations, will probably satisfy his curiosity; and the work may be transferred to the library for occasional reference, or taken as a travelling companion and guide to some interesting geological district.

But the Book *"must be swallowed, that is, read, but not curiously,"* by the reader desirous of forming a collection of organic remains. A general acquaintance with its contents, and a careful investigation of the characters of the fossils, and comparison with the figures and descriptions, will be requisite to enable the amateur collector to determine the nature of the specimens he may discover.

By the STUDENT the Book *"must be digested, that is, read wholly, and with diligence and attention."* He should fully comprehend one subject before he advances to the consideration of another, and should test the solidity of his knowledge by practical research. He should visit some of the localities described; collect specimens, and develope them with his own hands; examine their structure microscopically; nor rest satisfied until he has determined their general characters, and ascertained their generic and specific relations. Nor is this an arduous or irksome task; by a moderate degree of attention, a mind of average ability may quickly overcome the apparent difficulties, and will find in the knowledge thus acquired, and in the accession of mental vigour which such investigations never fail to impart, an ample reward for any expenditure of time and trouble.

It is, indeed, within the power of every intelligent reader, by assiduity and perseverance, to attain the high privilege of those who walk in the midst of wonders, in circumstances where the uninformed and uninquiring eye can perceive neither novelty nor beauty; and of being

> "Even as one,
> Who by some secret gift of soul or eye,
> In every spot beneath the smiling sun,
> *Sees where the Springs of living Waters lie!*

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Plate II. Frontispiece to Vol. II.
Plates III., IV., V., and VI., to follow the Table of Contents, and be placed opposite the description of each.
Lign. 247, to face page 770.

DESCRIPTION

OF THE

FRONTISPIECE OF VOL. I.

PLATE I.

Fig. 1.—A FERN in Coal-shale, from Leicestershire.
2.—A CRUSTACEAN in Limestone, from Solenhofen.
3.—A FISH (*Pycnodus rhombus*) in Limestone; from near Castel-a-mare.
4.—Half the Lower Jaw of a HYÆNA, from a fissure in a sandstone rock, near Maidstone.
5.—An AMMONITE, from the Isle of Portland.

DESCRIPTION OF THE VIGNETTE OF VOL. I.

A Group of Fossils, containing

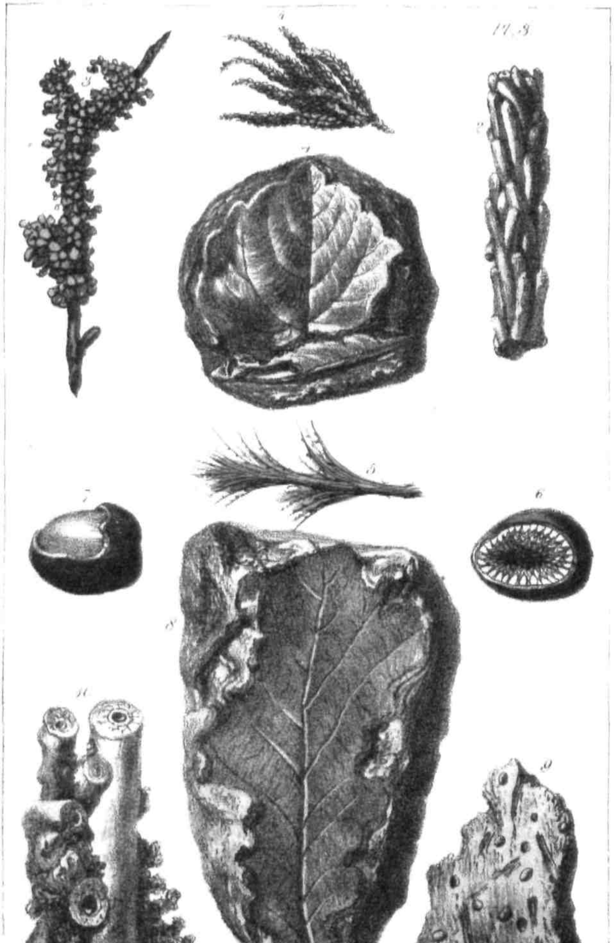
AMMONITES MANTELLII, from the *Chalk-marl*, Sussex.
TURRILITES COSTATUS, from the *Lower Chalk*, Rouen.
CHONDRITES BIGNORIENSIS, from the *Chalk-marl*, Sussex.
ECHINUS and FUSUS, from *Tertiary strata*, Palermo.

DESCRIPTION OF PLATE II.

The Frontispiece of Vol. II.

A Fossil Fish of the Salmon tribe, allied to the Smelt; from the Chalk, near Lewes, in Sussex.

[See Vol. II. pages 626 and 628.]



J. Dinkel del. G. Scharf lithog.   Printed by Hullmandel & Walton

DESCRIPTION OF PLATE III.

Incrustations, and Fossil Plants.

Figs. 1, 2, 3.—Twigs of Larch and Hawthorn, coated with tufa, or travertine, from having been exposed to the dripping of an incrusting spring; from Russia; see p. 39.

5.—A branch of recent *Chara*, with its fruit, with a thin pellicle of incrustation. Matlock.

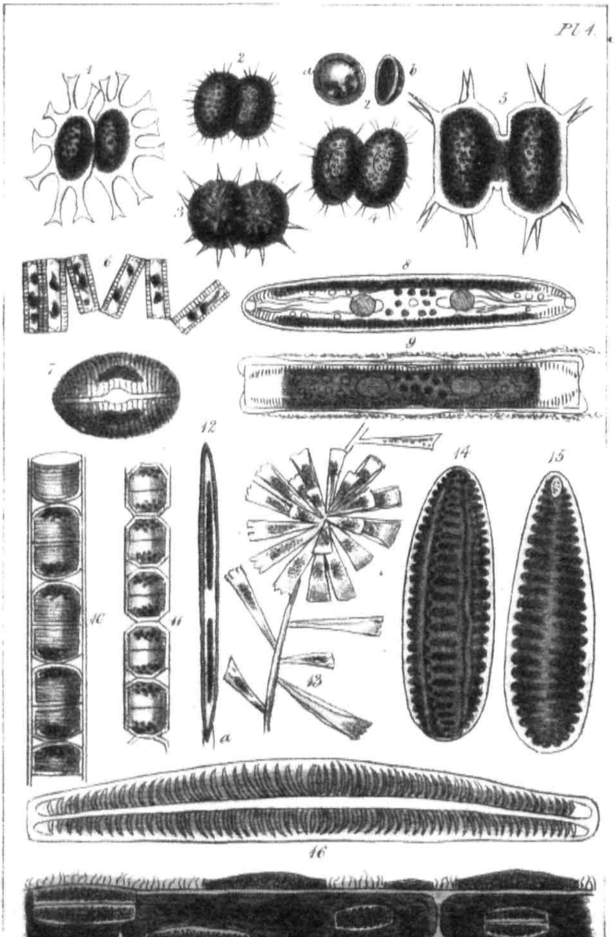
6, 7.—Hazel-nuts, from Belfast Lough: fig. 6 is lined with crystals of calcareous spar; fig. 7 is filled with a solid mass of the same mineral; see p. 71.

4, 8.—Impressions of Dicotyledonous Leaves in Gypseous Marlstone, from Stradella, near Pavia; see p. 201.

9.—Eocene Lacustrine or Fresh-water Limestone, from East Cliff Bay, Isle of Wight, with stems and seeds of Charæ: slightly magnified; see p. 195.

10.—Encrusted Twigs, from Matlock; the vegetable matter has perished, and left tubular cavities; see p. 39, and p. 873.

Pl. 1.



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DESCRIPTION OF PLATE IV.

Various species of recent Diatomaceæ, to illustrate the Fossil remains of this Tribe of Vegetables.

For detailed descriptions, see pages 87—100.

Figs. 1 to 5.—Various kinds of *Xanthidia:* figs. 2, 3, 4, found in a pond on Clapham Common, and fig. 1. living in a pond near Westpoint, United States.

1.—Xanthidium *furcatum:* $\frac{1}{24}$ of a line in diameter.

2.— ———— *hirsutum:* $\frac{1}{36}$.

3.— ———— *aculeatum:* $\frac{1}{24}$.

4.— ———— *fasciculatum:* $\frac{1}{24}$.

5.— ———————— variety of the above.

2*.—Pyxidicula operculata; Carlsbad, Bohemia: $\frac{1}{48}$ of a line in diameter.

6.—Bacillaria vulgaris. $\frac{1}{36}$ of a line in diameter. Pond on Clapham Common.

7.—*Cocconeis scutellum: from the Baltic:* $\frac{1}{24}$ of a line.

8.—Navicula viridis: $\frac{1}{6}$ of a line. Ponds on Clapham Common.

9.—The same; a side view; showing the currents produced in the water by the animal when in locomotion.

10.—Gallionella lineata: $\frac{1}{36}$ of a line. Ponds on Clapham Common.

11.—Gallionella moniliformis: $\frac{1}{72}$ of a line.

12.—Synhedra ulna: $\frac{1}{6}$ of a line: the point *a*, marks the pedicle of attachment. Ponds on Clapham and Wandsworth Commons.

13.—Podosphenia gracilis: $\frac{1}{12}$ *of* a line; attached to a thread *of Calothria.* and having by self-division formed a radiating cluster. Common in the ditches communicating with the Thames in Battersea-fields.

14.—Navicula splendida: $\frac{1}{12}$ of a line in diameter.

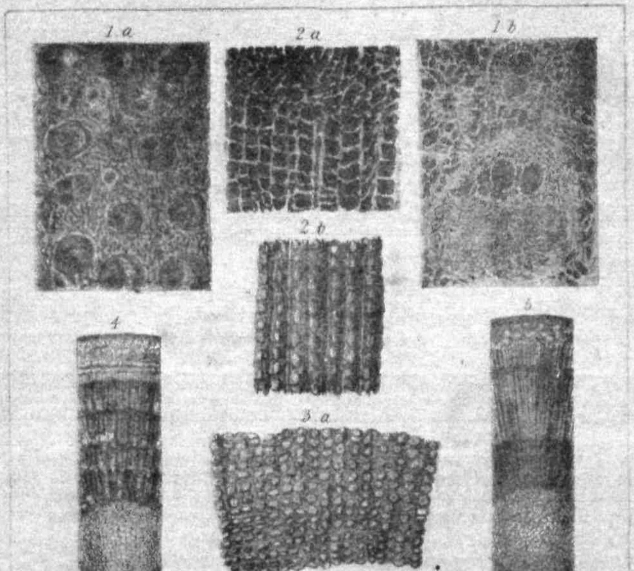
15.—Lateral view of the same.

DESCRIPTION OF PLATE IV.—*continued.*

Fig. 16.—Eunotia turgida: $\frac{1}{14}$ of a line; the empty shell, with sixty-five ribs, viewed laterally.

17.—A living group of the same: $\frac{1}{20}$ of a line: a piece of *Conferva rivularis*, beset with these animalcules. The smaller species are *E. Westermanni.*

[All the above organisms were figured and described by Ehrenberg as animals (*Polygastrica*), and are comprised in his family *Bacillaria*; they are now, however, regarded as unquestionably vegetable structures, belonging to the family of ALGÆ, termed *Diatomaceæ*.]



Dinkel del.

Lens Vlasius, Zin.

DESCRIPTION OF PLATE V.

Illustrative of the Structure of Fossil Vegetables.

Fig. 1.—Polished transverse section of silicified Monocotyledonous Wood, from Antigua; p. 185.

1a.—Magnified 20 times linear.

1b.—Magnified 75 times linear.

2a.—Transverse section of silicified Coniferous Wood (*Abies Benstedi*) from the Kentish Rag, near Maidstone (Iguanodon quarry), × 120 linear; p. 173.

2b.—Vertical or longitudinal section of the same, × 250 linear.

3a.—Transverse section of calcareous coniferous wood, from Willingdon, Sussex, × 80 linear; p. 173.

3b.—Longitudinal section of the above, × 120 linear.

4.—Slice of a transverse section of a recent Dicotyledonous Stem; showing, 1st, Pith or medullary column, occupying the centre; 2d, Four bands of woody layers, separated by condensed lines of elongated tissue in series, and having large regular openings of vessels, with numerous medullary rays running continuously from the central pith to the bark; 3d, the bark. (*From Mr. Witham.*)

5.—Slice of a transverse section of a recent gymnospermous phanerogamic stem (of a *Cycas*), having a central pith, with woody layers separated by a condensed line, and consisting of elongated cellular tissue, arranged in a regular series; medullary rays and bark. (*From Mr. Witham.*)

6.—Bundles of vascular tissue in *Stigmaria ficoides*, × 12 linear. See p. 135.

The two strands of vessels that appear as if on the surface (and are of a looser texture) are part of the vascular tissue of the stem, and become inflected (that is, bent over), and give rise to a band of vessels (the darker band seen between the above), that passes towards the bark or cortical covering.

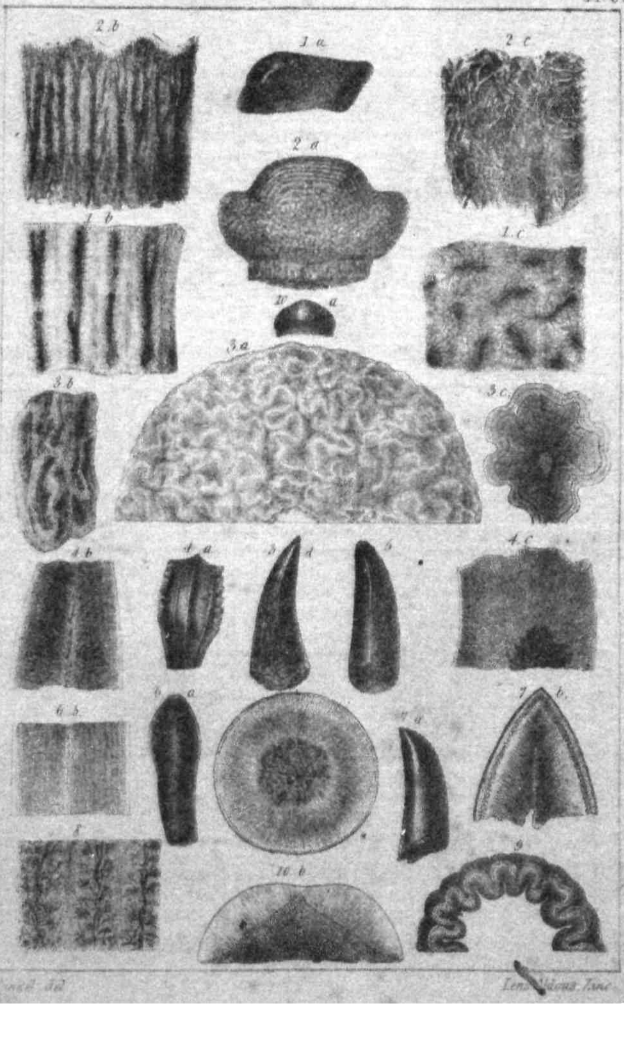
DESCRIPTION OF PLATE V.—*continued.*

Fig. 7.—Portion of a transverse section of one of the bundles of vascular tissue of *Sigillaria elegans*, × 20 linear. (*From M. Brongniart.*) See p. 131.

The convex portion on the left, and which in the original stem is situated towards the centre, is composed of the medullary vascular tissue formed of vessels irregularly disposed.

The longitudinal bundles are the woody fibres arranged in a radiated circle: the smooth interspaces are medullary rays.

The two distinct roundish spots of vascular tissue on the right of the ligneous zone occur irregularly on the outside of the woody circle, and are supposed to be detached bundles of the ligneous zone extending towards the leaves. See p. 131.



DESCRIPTION OF PLATE VI.

Illustrative of the Structure of Fossil Teeth.

Fig. 1*a*.—Tooth of ***Psammodus porosus***, from the Mountain Limestone. See p. 587.

1*b*.—Vertical section, a portion × 75 linear.

1*c*.—Transverse section of the same, × 75.

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THE

MEDALS OF CREATION.

INTRODUCTION.

"GEOLOGY, in the magnitude and sublimity of the objects of which it treats, ranks next to ASTRONOMY in the scale of the Sciences."—*Sir J. F. W. Herschel.*

GEOLOGY, a term signifying a discourse on the Earth, (from two Greek words: viz. γῆ, *ge*, the earth; and λόγος, *logos*, a discourse,) is the science which treats of the physical structure of the planet on which we live, and of the nature and causes of the successive changes which have taken place in the organic and inorganic kingdoms, from the remotest period to the present time, and is therefore intimately connected with every department of natural philosophy.

While in common with other scientific pursuits it yields the noblest and purest pleasures of which the human mind is susceptible, it has peculiar claims on our attention, since it offers inexhaustible and varied fields of intellectual research, and its cultivation, beyond that of any other science, is in a great measure independent of external circumstances; for

it can be followed in whatever condition of life we may be placed, and wherever our fortunes may lead us.

The eulogium passed by a distinguished living philosopher on scientific knowledge in general, is strikingly applicable to geological investigations. "The highest worldly prosperity, so far from being incompatible with them, supplies additional advantages for their pursuit; they may be alike enjoyed in the intervals of the most active business, while the calm and dispassionate interest with which they fill the mind, renders them a most delightful retreat from the agitations and dissensions of the world, and from the conflict of passions, prejudices, and interests, in which the man of business finds himself continually involved."*

From the present advanced state of geological science, particularly of that department which it is the more especial object of these volumes to elucidate, namely PALÆONTOLOGY,† or the study of Organic Remains,—it seems scarcely credible, that but little more than a century ago it was a matter of serious question with naturalists, whether the petrified shells imbedded in the rocks and strata were indeed shells that had been secreted by molluscous animals; or whether these bodies, together with the teeth, bones, leaves, wood, &c. found in a fossil state, were not formed by what was then termed the plastic power of the earth; in like manner as minerals, metals, and crystals.

In a "Natural History of England," published towards the end of the last century, it is gravely observed that at Bethersden in Kent, a kind of stone is found full of shells, "*which is a proof that shells and the animals we find in them living, have no necessary connexion.*" Another amusing instance of the ignorance on such subjects which

* Sir J. F. W. Herschel, "Discourse on the Study of Natural Philosophy."

† Palæontology: from παλαιὸς, *palaios*, ancient—ὄντα, *onta*, beings—λόγος, *logos*, a discourse.

prevailed at no remote period, occurs in a "History of the County of Surrey," in which it is stated that in a search for coal near Guildford the borers broke, and "this was thought by Mr. Peter Lely, the Astrologer, to have been the work of subterranean spirits, who wrenched off the augers of the miners, lest their secret haunts should be invaded."

But in the latter part of the seventeenth century, there were several eminent men in England who were greatly in advance of the age in which they lived, and strenuously exerted themselves to discover and promulgate the true principles of Geology. Among these, DR. MARTIN LISTER, physician to Queen Anne, was one of the most distinguished. This accomplished naturalist, in his great work on shells, which remains to this day a splendid monument of his labours, and of the talents and filial affection of his two daughters, by whom all the plates were engraved, figures and describes many fossil shells as real animal productions, and carefully compares them with recent species. He also recognised the distinction of strata by the organic remains they contain; and to him the honour is due of having first suggested the construction of geological maps;* he was likewise well acquainted with the position and extent of the Chalk and other strata of the South of England.†

From the foreign writers, who at an early period had obtained some correct notions of the structure of our planet, and of the nature of the revolutions it had undergone, I select the following beautiful and philosophical illustration of the physical mutations to which the surface of the earth is per-

* See Notes on the Progress of Geology in England, by W. H. Fitton, M.D. &c. *Philos. Mag.* vols. i. and ii. for 1832 and 1833.

† This celebrated physician and British geologist died in 1712, and was interred in the old church at Clapham; where a tablet to his memory is affixed to the outside of the north wall of St. Paul's Chapel.

petually subjected. It is from an Arabic manuscript of the thirteenth century ;* the narrative is supposed to be related by Rhidhz, an allegorical personage.

"I passed one day by a very ancient and populous city, and I asked one of its inhabitants how long it had been founded? 'It is, indeed, a mighty city,' replied he; 'we know not how long it has existed, and our ancestors were on this subject as ignorant as ourselves.' Some centuries afterwards I passed by the same place, but I could not perceive the slightest vestige of the city; and I demanded of a peasant, who was gathering herbs upon its former site, how long it had been destroyed? 'In sooth, a strange question,' replied he, 'the ground here has never been different from what you now behold it.' 'Was there not,' said I, 'of old a splendid city here?' 'Never,' answered he, 'so far as we know, and never did our fathers speak to us of any such.'

"On revisiting the spot, after the lapse of other centuries, I found the sea in the same place, and on its shores were a party of fishermen, of whom I asked how long the land had been covered by the waters? 'Is this a question,' said they, 'for a man like you? this spot has always been what it is now.'

"I again returned ages afterwards, and the sea had disappeared. I inquired of a man who stood alone upon the ground, how long ago the change had taken place, and he gave me the same answer that I had received before.

"Lastly, on coming back again, after an equal lapse of time, I found there a flourishing city, more populous and more rich in buildings than the city I had seen the first time; and when I fain would have informed myself regarding its origin, the inhabitants answered me, 'Its rise is lost in remote antiquity—we are ignorant how long it has existed, and our fathers were on this subject no wiser than ourselves.'"

We may smile at the ignorance of the inhabitants of the fabled cities, but are we in a condition to give a more satisfactory reply should it be inquired of us, "What are the physical changes which the country you inhabit has undergone?"—and yet cautious observation, and patient and unprejudiced investigation, are alone necessary to enable us to answer the interrogation.

* Quoted by Sir C. Lyell in his "Principles of Geology."

Dismissing from his mind all preconceived opinions, the student must be prepared to learn that the earth's surface has been, and still is, subject to perpetual mutation,—that *the sea and land are continually changing place*,—that what is now dry land was once the bottom of the deep, and that the bed of the present ocean will, in its turn, be elevated above the water and become land,—that all the solid materials of the globe have been in a softened, fluid, or gaseous state,—that the relics of countless myriads of animals and plants are entombed in the rocks and strata,—and that vast mountain-chains, and extensive regions, are wholly composed of the petrified remains of beings that lived and died in periods long antecedent to the creation of the human race. Astounding as are these propositions, they rest upon evidence so clear and incontrovertible, that they cannot fail *to be admitted by every intelligent and unprejudiced reader*, who will bestow but a moderate share of attention to the examination of the phenomena, of which the following pages present a familiar exposition.

I cannot conclude these introductory observations, without adverting to the incalculable benefits which result from scientific pursuits in general, and of Geology in particular. An able modern writer has justly remarked :—" It is fearfully true, that nine-tenths of the immorality which pervades the better classes of society, originate from the want of an interesting occupation to fill up the vacant time ; and as the study of the natural sciences is as attractive as it is *beneficial, it must necessarily* exert a *moral* and even religious influence upon the young and inquiring mind. The youth who is fond of scientific pursuits will not enter into revelry, for frivolous or vicious excitements will have no fascination for him. The overflowing cup, the unmeaning or dishonest game, will not entice him. If any one doubts the beneficial influence of these studies on the morals and character, I would ask him to point out the immoral young

man who is devotedly attached to any branch of natural science: I never knew such an one. There may be such individuals—for religion only can change the heart—but if there be, they are very rare exceptions; and the loud clamours which are always raised against the man of science who errs, prove how rarely the study of the works of the Creator fails to exert an ennobling effect upon a well-regulated mind. Fortunate, indeed, are the youth of either sex, who early imbibe a taste for natural knowledge, and whose predilections are not thwarted by injudicious friends."

And while Geology exerts this hallowing influence on the character, it possesses the great advantage of presenting subjects adapted to every capacity; on some of its investigations the highest intellectual powers and the most profound acquirements in exact science are required; while many of its problems may be solved by any one who has eyes and will use them; and innumerable facts illustrative of the ancient condition of our planet, and of its inhabitants, may be gathered by any diligent and intelligent observer.

But it is surely unnecessary to dwell on the interest and importance of a study, which instructs us that every pebble we tread upon bears the impress of the Almighty's hand, and affords evidence of Creative wisdom; that every grain of sand, every particle of dust scattered by the wind, may be composed of the aggregated skeletons of beings, so minute as to elude our unassisted vision, but which possessed an organization as marvellous as our own;—a science whose discoveries have realized the wildest imaginings of the poet,—whose realities far surpass in grandeur and sublimity the most imposing fictions of romance;—a science, whose empire is the earth, the ocean, the atmosphere, the heavens; —whose speculations embrace all elements, all space, all time;—objects the most minute, objects the most colossal; —carrying its researches into the smallest atom which the

microscope can render accessible to our visual organs,—and comprehending all the phenomena in the boundless Universe, which the powers of the telescope can reveal.

And as no branch of natural philosophy can more strongly impress the mind with that deep sense of humility and dependence, which the contemplation of the works of the Eternal is calculated to inspire, so none can more powerfully encourage our aspirations after truth and wisdom. Every walk we take offers subjects for profound meditation, —every pebble that attracts our notice, matter for serious reflection; and contemplating the incessant dissolution and renovation which are taking place around us in the organic and inorganic kingdoms of naturé, we are struck with the force and beauty of the exclamation of the poet—

> "My heart is awed within me, when I think
> Of the great miracle which still goes on
> In silence round me—the perpetual work
> Of THY Creation, finished, yet renewed
> For ever!

PRELIMINARY REMARKS.

ON THE PLAN OF THE WORK, AND THE ARRANGEMENT AND SUBDIVISION OF THE SUBJECTS IT EMBRACES.

WITH the view of economizing space, I would refer the reader to the following volumes for figures and descriptions of such fossils as are illustrated therein: by this arrangement I hope to afford the student a comprehensive view of Paleontology, and yet restrict this work within the limits which as a manual it would be inconvenient to exceed; at the same time it will be complete in itself, and afford all the information required by the amateur collector and general reader.

I. DR. BUCKLAND'S *Bridgewater Treatise:* 2 vols. 8vo.—These volumes contain numerous excellent figures of organic remains; and as the work is, or ought to be, found in every good public or private library in the kingdom, it will be accessible to most of my readers.

II. *The Wonders of Geology, or a Familiar Exposition of Geological Phenomena; sixth* edition, in two vols. with coloured plates, and numerous figures; by the AUTHOR. Price 18*s.*—This work is designed to afford a general view of Geological phenomena, divested as much as possible of scientific language: it is illustrated by numerous figures of organic remains.

III. *Geological Excursions round the Isle of Wight and along the adjacent Coasts of Hampshire and Dorsetshire.* One volume, richly illustrated. By the AUTHOR. Price 12*s.*

• IV. *Petrifactions and their Teachings; or a Hand-book to the Gallery of Organic Remains in the British Museum.* One vol. with many original figures of the most interesting objects. By the AUTHOR.* Price 5*s.*

V. *A Pictorial Atlas of Fossil Remains;* consisting of *Coloured Illustrations* selected from "Parkinson's Organic Remains of a Former World," and Artis' "Antediluvian Phytology." 1 vol. 4to. with seventy-four coloured plates, and several lignographs, containing nearly 900 figures of fossils. By the AUTHOR. Price 2*l.* 2*s.*

To the above may be added DANA'S *Mineralogy*, which treats of the various mineral substances that enter into the composition of the rocks and strata in which the fossil remains are imbedded.

A good geological map of Great Britain is indispensable. The small map published by the Society for the Diffusion of Useful Knowledge, edited by Sir R. Murchison, price 5*s.*, is an excellent compendium; but Mr. Knipe's large "*Geological Map of the British Isles*" is the most complete and convenient for the traveller: price 3*l.* 3*s.* By reference to the map, the geological structure, and the prevailing fossils of a district, may be ascertained.

The above works are referred to as follows: viz.

Bd. Dr. Buckland's Treatise.
Wond. The Wonders of Geology.
Geol. I. of W. Geology of the Isle of Wight.
Petrifactions. Petrifactions and their Teachings.
Pict. Atlas. Pictorial Atlas of Organic Remains.

* The three works above named consist of four volumes uniform with the present edition of the "Medals of Creation:" this series of six volumes comprises the popular geological works of the Author.

The following works, to which reference will often be made, are thus denoted :—

Foss. Flor. The Fossil Flora of Great Britain, by Dr. Lindley, and W. Hutton, Esq. 3 vols. 8vo.

Veg. Foss. Histoire des Végétaux Fossiles, par M. Adolphe Brongniart. 1 vol. 4to.

Geol. Trans. Transactions of the Geological Society of London. 5 vols. 4to. ; and New Series, in 5 vols.

Geol. Proc. Geological Proceedings.

—— *Journ.* ———— Quarterly Journal.

Sil. Syst. The Silurian System, by Sir R. I. Murchison. 2 vols. 4to. with plates and map.

Org. Rem. Parkinson's Organic Remains of a Former World. 3 vols. 4to.

Oss. Foss. Ossemens Fossiles, par Baron Cuvier. 5 vols. 4to. 5[me.] edit.

Min. Conch. Sowerby's Mineral Conchology. 6 vols. 8vo.

Odont. Odontography ; a Treatise on the Comparative Anatomy of the Teeth, by Professor Owen. 2 vols. 8vo.

Brit. Mam. British Fossil Mammalia ; by the same Author. 1 vol. 8vo.

Brit. Rep. Reports on British Fossil Reptiles in the British Association Transactions for 1839, and 1841 ; by the same Author.

Phil. York. Geology of Yorkshire, by Professor John Phillips. 2 vols. 4to.

South. D. Fossils of the South Downs, 1 vol. 4to. 42 plates by the Author. 1822.

Geol. S. E. Geology of the South-east of England. 1 vol. 8vo. by the same.

Tilg. For. Fossils of Tilgate Forest. 1 vol. 4to. 20 plates ; by the same. 1827.

Poiss. Foss. Recherches sur les Poissons Fossiles, par M. Agassiz. 4 vols. 4to, and 2 vols. folio.

Man. Geol. Manual or Elements of Geology, by Sir C. Lyell. 1 vol. 8vo. Edit. 1852.

The following abbreviations are also employed:—

§ 1. *Relative to the Rocks or Strata.*

Drift. Alluvial deposits, or Drift.
Tert. Tertiary. *Lond. C.* London clay.
Cret. Cretaceous formation. *U. Ch.* Upper chalk. *L. Ch.* Lower chalk.
Trias. New Red Sandstone, or Triassic deposits.
Carb. Carboniferous or Coal formation.
Mt. L. Mountain or Carboniferous limestone.
Devon. Devonian or Old Red Sandstone formation.
Sil. Syst. Silurian System, or formation.

§ 2. *Relative to Organic Remains.*

nat. Natural size.
× Magnified in diameter: *e.g.* × 8, magnified eight diameters, &c.
× × Highly magnified; the degree not accurately determined.
inv. Invisible to the naked eye.
— Less than natural: *e.g.* — $\frac{2}{3}$, reduced to two-thirds the diameter of the original.
Lign. Lignograph or woodcut.

Explanation of Terms.—Upon the occurrence of a scientific word apparently requiring explanation, the *meaning*, where practicable, is for the most part given in a parenthesis; for example, Caulopteris (*fern-stem*); Phascotherium (*pouch-animal*); carboniferous (*coal-bearing*); except in the case of arbitrary names, and of those whose derivation cannot be concisely expressed.* With the view of rendering these volumes more generally useful, English terminology is in

* Upwards of 300 scientific terms are explained in the Glossary, "Wonders," vol. ii. p. 915—921.

many instances made use of, though involving inelegance of expression.

The work is divided into four parts: the first is an *Introduction to the Study of Organic Remains;* the second treats of *Fossil Botany;* the third embraces *Fossil Zoology;* and the fourth, under the head of *Geological Excursions*, illustrates the principles enunciated in the course of the work, by practical observations on a few instructive British localities.

PART I.

1. On the British Strata and their Fossils.
2. Arrangement and Characters of the British Formations.
3. On the Nature of Fossils or Organic Remains.
4. On Mineralized Vegetable Remains, and the mode of conducting their investigation.
5. On Peat, Lignite, and Coal.

PART II.

FOSSIL BOTANY.

Classification of Fossil Vegetables.

1. On the Fossil Remains of Cryptogamiæ.
2. „ „ Diatomaceæ.
3. „ „ Ferns.
4. „ „ Sigillariæ.
5. „ „ Lepidodendra.
6. „ „ Cycadaceæ.
7. „ „ Coniferæ.
8. „ „ Palms.
9. „ „ Angiosperms.

Retrospect.

British Localities of Fossil Plants.

PART III.

FOSSIL ZOOLOGY.

On the Fossil Remains of the Animal Kingdom.

1. Zoophytes; Amorphozoa.
2. " Polypifera.
3. Echinoderms; comprising the
    - *a.* Crinoidea, or Lily-shaped animals.
    - *b.* Asteriada, or Star-Fishes.
    - *c.* Echinida, or Sea-Urchins.
4. Foraminifera.
5. Shell-bearing Mollusca.
6. Articulated animals; comprising
    - *a.* Crustaceans.
    - *b.* Insects.
7. Fishes.
8. Reptiles.
9. Birds.
10. Mammalia.
11. Man.

Retrospect.

PART IV.

I. Geological Excursions in various parts of England, illustrative of the method of observing geological phenomena, and of collecting Fossil Remains.

II. Miscellaneous.
On the prices of Fossils; lists of Dealers, &c.

III. Appendix.

PART I.

CHAPTER I.

ON THE NATURE AND ARRANGEMENT OF THE BRITISH STRATA, AND THEIR FOSSILS.

"To discover order and intelligence in scenes of apparent wildness and confusion is the pleasing task of the geological inquirer."—Dr. Paris.

The solid materials of which the earth is composed, from the surface to the greatest depths within the reach of human observation, consist of minerals and fossils.

Minerals are inorganic substances formed by natural operations, and are the product of chemical or electro-chemical action.

Fossils are the durable remains of animals and vegetables which have been imbedded in the strata by natural causes in remote periods, and subsequently more or less altered in structure and composition by mechanical and chemical agencies.

The soft and delicate parts of animal and vegetable organisms rapidly decompose after death; but the firmer and denser structures, such as the bones and teeth of the former, and the woody fibre of the latter, possess considerable durability, and, under certain conditions will resist decay for

many years, or even centuries; and when deeply imbedded in the earth, protected from atmospheric influences, and subjected to the conservative effects of various mineral solutions, the most perishable tissues often resist decomposition, and becoming transformed into stone, may endure for incalculable periods of time. The calcareous and siliceous cases or frustules of numerous microscopic plants are so indestructible, and occur in such inconceivable quantities, that the belief of some eminent naturalists of the last century, that every grain of flint and lime in certain rocks, may have been elaborated by the energies of vitality, can no longer be regarded as an extravagant hypothesis. Some idea may be formed of the large proportion of the solid materials of the globe that has unquestionably originated from this source, by a reference to the list of strata which are wholly, or in great part, composed of animal and vegetable structures, given in the "Wonders of Geology," p. 888.

There are also immense tracts of country that consist in a great measure of the remains of plants in the state of anthracite, coal, lignite, &c.; and districts covered with peat-bogs and subterranean forests.

Although these relics of animal and vegetable organisms are found in almost every sedimentary deposit, yet they occur far more abundantly, and in a better state of preservation, in some strata than in others: nor are they equally distributed throughout the same bed, but are heaped together in particular localities, and occur but sparingly, or are altogether absent, in other layers of the same rock. Neither are the remains of the same kinds of animals and plants found indiscriminately in strata of different ages: on the contrary, many species are restricted to the most ancient, others to the most recent formations; while some genera range through the entire series of deposits, and also appear as denizens of the existing seas. Hence organic remains

acquire a high degree of importance, not only from the intrinsic interest they possess as objects of natural history, but also for the light they shed on the physical condition of our planet in the remotest ages, and for the data they afford as to the successive physical revolutions which the surface of the earth has undergone.

Fossils have been eloquently and appropriately termed MEDALS OF CREATION; for as an accomplished numismatist, even when the inscription of an ancient and unknown coin is illegible, can from the half-obliterated effigy, and from the style of art, determine with precision the people by whom, and the period when, it was struck; in like manner the geologist can decipher these natural memorials, interpret the hieroglyphics with which they are inscribed, and from apparently the most insignificant relics, trace the history of beings of whom no other records are extant, and ascertain the forms and habits of unknown types of organization whose races were swept from the face of the earth, ere the creation of man and the creatures which are his contemporaries. Well might the illustrious Bergman exclaim, "*Sunt instar nummorum memorialium, quæ de præteritis globi nostri fatis testantur, ubi omnia silent monumenta historica.*"

To derive from these Medals of Creation all the information they are capable of affording, regard therefore must be had not only to their peculiar characters, but also to the geological relations of the strata in which they are imbedded. Data may be thus obtained by which the relative age of a formation or group of strata can be determined, as well as the mode of deposition, and the agency by which it was effected; whether in the bed of an ocean, or of a lake, or estuary,—by the action of the sea, or of rivers, or running streams,—by the effects of icebergs or glaciers,—by slow processes through long periods of time, or by sudden inundations or deluges,—or by the agency of volcanoes and earthquakes.

The discovery that particular fossils are confined to certain deposits, was soon productive of important results, which greatly tended to the advancement of modern Geology; for although Dr. Lister, more than a century before, had obtained a glimpse of this law, its principles were neither understood nor regarded in this country until the late Dr. William Smith, by his own unaided exertions, proved by numerous observations on the British strata, its value and applicability for the identification of a deposit, in districts remote from each other.

This phenomenon did not escape the notice of the distinguished French philosophers, MM. Cuvier and Brongniart, who in their admirable work, "*Géographie Minéralogique des Environs de Paris,*" enunciated the same principle:—

> "Le moyen que nous avons employé pour reconnoître au milieu d'un si grand nombre de lits calcaires, un lit déjà observé, dans un canton très-éloigné, est pris de la nature des fossiles renfermés dans chaque couche; ces fossiles sont toujours généralement les mêmes dans les couches correspondantes, et présentent d'un système de couche à un autre système, des différences d'espèces assez notables. C'est un signe de reconnoissance qui jusqu'à présent ne nous a pas trompés." *

Now, though recent discoveries have shown that this rule has many exceptions, and that its too stringent adoption has been productive of some erroneous generalizations, yet if employed with due caution it is fraught with the most interesting results, and is the only certain basis of our knowledge respecting the appearance, continuance, and extinction, of the lost races of animals and plants, which were once denizens of our planet.

In the "Wonders of Geology" will be found a comprehensive sketch of the composition and arrangement of the several formations or groups of strata; and a reference to that work will afford the student the necessary information

* Géog. Min. Oss. Foss. tom. ii. p. 266.

on this branch of Geology. For the convenience of the general reader I subjoin a synoptical view of the characters and relations of the British fossiliferous deposits.

The total thickness of the entire series of rocks within the scope of human examination, is estimated at from fifteen to twenty miles, reckoning from the summits of the highest mountains to the greatest depths hitherto penetrated; and as this vertical section scarcely amounts to $\frac{1}{400}$th of the diameter of the globe, it is familiarly termed the Earth's crust. The substances of which the sedimentary strata are composed have been deposited by the action of water, and subsequently more or less modified in structure and composition by heat, and by electro-chemical forces. The superficial accumulations of water-worn detritus, consisting of gravel, boulders, sand, clay, &c. are termed *Drift*, or *Alluvial* deposits. When the successive layers in which the sediments subsided are obvious, the deposits are said to be *stratified;* when the nature of the materials has been altered by igneous action or high temperature, but the lines of stratification are not wholly effaced, the rocks are denominated *metamorphic* (*transformed*). When all traces of organic remains and of sedimentary deposition are lost, and the mass is crystalline, and composed of known products of igneous action, such rocks are named *plutonic*, as granite, sienite, trap, basalt, porphyry, and the like. Lastly, rocks resembling the lavas, scoriæ, and other substances emitted by burning mountains still in activity, are called *volcanic*.

The sedimentary origin ascribed to ancient crystalline rocks is, of course, hypothetical, since all evidence of aqueous deposition is wanting, and the minerals (*mica*, *quartz*, and *felspar*) of which they are so largely constituted, are not readily soluble in water under ordinary circumstances. But rocks unquestionably deposited by water, when exposed to intense heat under great pressure, acquire a crystalline structure (*Wond.* p. 864); and a series of changes, from a

loose earthy deposit, to compact volcanic lava, may be traced in numerous instances, so as to leave but little doubt that the rocks called primitive or primary, *may* have originally been either argillaceous, siliceous, or calcareous strata, abounding in organic remains (*Wond.* p. 873). These crystalline masses have been formed at successive periods; for granite is found of all ages, occurring in the most ancient, as well as in comparatively modern epochs. The difference between the composition and aspect of these rocks, and those of recent volcanoes, is with much probability ascribed to the fact that the latter are of sub-aerial origin; that is, were erupted on the surface, and the gaseous products in consequence escaped; while the former were ejected at great depths, either beneath the sea, or under immense accumulations of other deposits, and being thus subjected to great pressure, the volatile elements were confined, and formed new combinations: in like manner as chalk when burnt in the open air is converted into lime, the carbonic acid gas escaping; but when exposed to the same degree of heat in a closed iron tube, is transformed into granular marble (*Wond.* p. 104).

From these ancient crystalline rocks generally underlying the sedimentary deposits, and never appearing as if they had been ejected from a crater, the term *hypogene** (*nether-formed*) is employed by Sir C. Lyell to designate the whole class; and they are subdivided into, 1. *plutonic*, those in which all traces of sedimentary origin are lost, as granite; and 2. *metamorphic*, those which still manifest traces of stratification, as mica-schist, &c.

The fossiliferous rocks are, for the convenience of study, separated into three grand divisions.

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* Nether-formed, from ὑπὸ, *hypo*, under; and γίνομαι, *ginomai*, to be formed.

1. The TERTIARY; comprising the deposits between the Chalk and the superficial Drift and modern Alluvium.

2. The SECONDARY; from the *Chalk* to the *Trias or New Red*, inclusive.

3. The PALÆOZOIC; from the *Permian* to the *Silurian;* including the vast series of unfossiliferous slate rocks termed the *Cambrian*, in which all traces of organic remains are lost.

In the following arrangement the strata are enumerated as if lying in regular sequence, one beneath the other; but in nature such an unbroken series has never been observed. A few groups only occur in a serial order, and these but rarely in their original position. The beds are for the most part disrupted, and lie in various angles of inclination; sometimes they are completely retroverted, the newer strata underlying those upon which they were originally deposited. The order of succession has been ascertained by careful observation of the relative super-position of the respective members of the series in different countries; and from an immense number of facts collected by able observers in every part of the globe.

This synopsis presents a chronological arrangement of the rocks according to the present state of geological knowledge, but it must not be supposed that these rigid distinctions, these hard lines, which are necessary to facilitate the acquisition of a general idea of the phenomena attempted to be explained, exist in nature. By whatever names we designate geological periods, there appear to be no clearly defined boundaries between them in reference to the whole earth: such well marked lines may be seen in particular localities, but daily experience teaches us that there is a blending, and a gradual and insensible passage, from the lowest to the highest sedimentary strata, particularly in respect of fossil remains. The terms employed to designate formations can only be considered as expressing the

predominance of certain characters, to be used provisionally, as a convenient mode of classifying and generalizing the facts collected, whilst that knowledge is accumulating which in after times will reveal the nature and order of succession of the principal events in the earth's physical history.*

Dr. Buckland's "Bridgewater Treatise" (Vol. II. *frontispiece*) contains a comprehensive Diagram of the rocks and strata of which the crust of the earth is composed; it was drawn by the late Mr. Thomas Webster.

* "Wonders of Geology," p. 892.

CHAPTER II.

SYNOPSIS OF THE BRITISH STRATA.

"Hard lines are admissible in Science, whose object is not to imitate Nature, but to interpret her works."—GREENOUGH.

THE classification of the stratified rocks is based on three principal characters; namely, 1, the mineral structure; 2, the order of superposition; and 3, the nature of the organic remains; the following synopsis has been drawn up in accordance with these principles.*

CHRONOLOGICAL ARRANGEMENT OF THE BRITISH FORMATIONS.

COMMENCING WITH THE UPPERMOST OR NEWEST DEPOSITS.

Modern or Human Epoch.

ALLUVIAL DEPOSITS: remains of Man and existing species of mammalia.

Post-Pliocene.

DRIFT; Boulder clay; Till; &c. comprising the superficial irregular accumulations of transported materials, consisting of gravel, boulders, sand, clay, &c.

Observations.—These beds have been formed by a variety of causes; by land-floods and inundations, by irruptions of the sea, and by the

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* See "Wonders of Geology," vol. i. pp. 200—207, for a Synoptical Table of the principal rocks.

agency of glaciers and icebergs. They are the catacombs of the extinct colossal mammalia—of the mastodon, mammoth, rhinoceros, hippopotamus, elk, horse, ox, whale, &c. They cannot be definitively separated from those of the Modern or Human epoch, for the gravel beds near Geneva, which closely resemble the newest tertiary drift in materials and position, abound in bones of animals, almost all of which belong to existing species.*

Tertiary Epochs.

An extensive series, comprising many isolated groups of marine and lacustrine deposits, containing fossil remains of animals and vegetables of all classes; the greater number of genera and species in the most ancient or lowermost beds belong to extinct types.

Subdivisions :—

1. The PLIOCENE† (*more new, or recent.*‡ *Wond.* p. 221); strata in which the shells are for the most part of recent species, having only about ten per cent of extinct forms. (*Norwich Crag.*)

2. The MIOCENE (*less recent,*‖ *Wond.* p. 221); containing about 20 per cent of recent species of shells. (*Suffolk Crag.*)

3. The EOCENE (*dawn of recent,*§ in allusion to the first appearance of recent species—*Wond.* p. 226); the most ancient tertiary strata contain but very few existing species of shells; not more than five per cent. (*London, Hants, and Paris basins.*)

* See M. Pictet's "*Palæontologie.*"

† In the present state of our knowledge, this arrangement is of great utility, but it will probably require considerable modification, and must, perhaps, hereafter be abandoned; for it cannot be doubted, that strata in which no recent species have yet been found, may yield them to more accurate and extended observations, and those in which only a few recent species are associated with a large number of extinct forms, may have these proportions reversed.

‡ From πλείων, *pleion*, more; and καινὸς, *kainos*, recent.

‖ From μείων, *meion*, less, and *recent.*

§ From ἠὼς, *eos*, the dawn or commencement, and *recent.*

Obs.– The marine are often associated with fresh-water deposits, and the general characters of the Tertiary system are alternations of marine and lacustrine strata. In England the most important Tertiary deposits are those of the London basin, the Isle of Sheppey, the south-western coasts of Sussex and Hampshire, the north of the Isle of Wight, and the eastern coasts of Essex, Norfolk, Suffolk. (*Wond.* p. 226.)

Secondary Epochs.

THE CRETACEOUS OR CHALK FORMATION. (*Wond.* p. 296). A marine formation, comprising a vast series of beds of limestone, sandstone, marl, and clay, &c.; characterized by remains of extinct zoophytes, mollusks, cephalopods, echinoderms, crustaceans, fishes, &c.; lacertians, crocodilians, chelonians, and other extinct reptiles; drifted coniferous and dicotyledonous wood and foliage, fuci, &c.

Subdivisions:—

1. The *Maestricht beds.* Friable coralline and shelly limestones, with flints and chert.

2. *Upper Chalk*, with flints	*Craie blanche* of the French geologists.
3. *Lower Chalk*, without flints...	
4. *Chalk-Marl*	*Craie tufeau.*
5. *Firestone*, Malm-rock, Upper Greensand, or Glauconite ...	*Glauconie crayeuse.*
6. *Galt*, or Folkstone-marl.....	*Glauconie sableuse.*
7. *Shanklin*, or Lower Greensand.	*Formation néocomien*, which is divided into *N. supérieur*, the English upper divisions of the Greensand or Kentish rag; and *N. inférieur*, the lower beds of sand and clay, of the southern shore of the Isle of Wight, at Atherfield.*

* Another subdivision, with *other* names (chiefly derived from French localities), has lately been proposed by M. D'Orbigny; which I notice with the more regret, since this eminent naturalist formerly

Obs.—The Maestricht beds are chiefly composed of fawn-coloured limestones of friable texture; containing peculiar species of corals, shells, fishes, reptiles, &c. The *Chalk* is generally white, but in some localities is of a deep red, in others of a yellow colour; nodules, layers, and veins of flint occur in the upper, but are seldom present in the lower chalk. The *Marl* is an argillaceous limestone, which generally prevails beneath the white chalk; it sometimes contains a large intermixture of green or chlorite sand, and then is called *Firestone*, or *Glauconite*. The *Galt* is a stiff, blue or blackish clay, abounding in shells which frequently retain their pearly lustre. The *Greensand* is a triple alternation of sands and sandstones with clays; and beds of cherty limestone called *Kentish Rag*.

The WEALDEN; a formation, whose fluviatile character was first observed and established by the researches of the author (*Wond.* p. 360). A series of clays, sands, sandstones and limestones, with layers of lignite, and extensive coal-fields; characterized by the remains of several peculiar terrestrial reptiles, namely, *Iguanodon*, *Hylæosaurus*, *Pelorosaurus*, *Megalosaurus*; *Crocodilians* and *Chelonians*; *Enaliosaurians*; *Pterodactyles*, &c.; Fishes of fluviatile and marine genera; Insects of several orders; fresh water mollusks and crustaceans; conifers, cycads, ferns, &c.

Subdivisions:—

1. *Weald-clay*, with Sussex or Petworth marbles.
2. *Tilgate-grit*, and *Hastings* sands.
3. *Ashburnham* clays, shales, and grey limestones.
4. *Purbeck beds*; argillaceous and calcareous shales, and fresh-water limestones and marbles. Petrified forest, and layers of vegetable earth; with Cycads and Conifers.

Obs.—Clays and limestones, almost wholly composed of fresh-water snail-shells, and minute crustaceans, generally occupy the

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repudiated the censurable practice of many modern systematists, of changing established names of strata and fossils, without any just cause. The British geologist will smile to see the Wealden Formation —so eminently distinguished in England and Germany by its extent, thickness, and remarkable fauna and flora,—ranked as a subordinate member of the "*Formation néocomien*," of France.

uppermost place in the series in Sussex; sands and sandstones, with shales, and lignite, prevail in the middle; while in the lowermost, argillaceous beds, with shelly marbles or limestones, again appear; and, buried beneath the whole, is a petrified pine-forest, with the trees still erect, and the vegetable mould undisturbed! The upper clay beds and marbles form the deep valleys or Wealds of Kent and Sussex, and the middle series constitutes the Forest-Ridge. The Purbeck strata are obscurely seen in some of the deepest valleys of eastern Sussex; they emerge on the Dorsetshire coast, form the Island or Peninsula whose name they bear, and surmount the northern brow of the Isle of Portland. On the southern coast of the Isle of Wight, the Wealden beds emerge from beneath the Greensand strata between Atherfield and Compton Bay on the western limit, and in Sandown Bay on the eastern; and their characteristic fossils are continually being washed up on the sea-shore.

THE JURASSIC OR OOLITIC FORMATION. (*Wond.* pp. 202, and 491). A marine formation of great extent and thickness, consisting of strata of limestone and clay, which abound in extinct species and genera of marine shells, Corals, Insects, Fishes, and terrestrial and marine Reptiles. Land plants of many peculiar types, and the remains of two genera of MAMMALIA.

Subdivisions:—

Upper Oolite of Portland, Wilts, Bucks, Berks, &c.	1. *Portland Oolite.* Limestone of an oolitic structure, abounding in ammonites, trigoniæ, &c. and other marine exuviæ. Green and ferruginous sands—layers of chert. 2. *Kimmeridge clay.* Blue clay, with septaria, and bands of sandy concretions—marine shells and other organic remains—*ostrea deltoidea.* Beds of lignite.
Middle Oolite of Oxford, Bucks, Yorkshire, &c.	1. *Coral oolite,* or Coral rag. Limestone composed of corals, with shells and echinites. 2. *Oxford clay*; with septaria and numerous fossils. Beds of calcareous grit, called *Kelloway-rock,* swarming with organic remains.

Lower Oolite of Gloucestershire, Oxfordshire, and Northamptonshire.	1. *Cornbrash*—a coarse shelly limestone. 2. *Forest marble;* concretions of fissile arenaceous limestone—coarse shelly oolite—sand, grit, and blue clay. 3. *Great oolite*—calcareous oolitic limestone and freestone; reptiles, corals, &c., upper beds full of shells. *Stonesfield slate;*—terrestrial plants, insects, reptiles, *Mammalia.* 4. *Fuller's earth beds;*—marls and clays, with fuller's earth—sandy limestones and shells. 5. *Inferior oolite*—coarse limestone—conglomerated masses of terebratulæ and other shells—ferruginous sand, and concretionary blocks of sandy limestone, and shells.
Lower Oolite, of Brora in Scotland.	1. *Shelly limestones*—alternation of sandstones, shales, and ironstone; land-plants. 2. *Ferruginous limestone,* with carbonized wood and shells. 3. *Sandstone and shale; with two beds of coal.*
Lower Oolite of the Yorkshire coast.	1. *Cornbrash*—a provincial term for a bluish grey rubbly limestone, with intervening layers of clay. 2. *Sandstones and clays,* with land-plants, thin beds of coal and shale—calcareous sandstone and shelly limestone. 3. *Sandstone*—often carbonaceous, with clays; coal-beds, and iron-stone, with remains of vegetables. 4. *Limestone;* ferruginous and concretionary sands.

Obs.—The difference observable between the lower beds of the Oolite in the midland counties, and those of Yorkshire and Scotland, is a fact of considerable interest. The fluvio-marine accumulations of vegetable matter in the state of coal, with the remains of land-plants at Scarborough and Brora, together with the presence of insects, fresh-water crustaceans, mammalia, and terrestrial plants, in the Stonesfield slate, attest the existence of neighbouring land, and the action of rivers and currents.

THE LIAS. (*Wond.* p. 521). A series of clays, shales, and limestones, with marine shells, cephalopoda, crinoidea,

and fishes in great abundance; reptiles, (particularly of two extinct genera, *Plesiosaurus*, and *Ichthyosaurus*,) in immense numbers. Drifted wood and land plants: coniferæ, cycadeæ, &c.

Subdivisions:—

1. Upper lias shale, full of saurian remains, belemnites, ammonites, &c. intercalated with the lowermost beds of the Oolite: nodules and beds of limestone.

2. Lias marlstone; calcareous, sandy, and ferruginous strata, very rich in terebratulæ and other marine shells.

3. Lower lias clay and shale, abounding in *gryphea incurva*, and other marine shells; intercalations of sands and clays, with nodules of limestone.

4. Lias rock; a series of laminated limestones, with clay partings. Bone-bed, with numerous remains of fishes.

Obs.—The Lias is the grand depository of those tribes of marine reptiles, the *Ichthyosauri* and *Plesiosauri*, whose remarkable forms, structure, and state of preservation, have excited the attention even of the most incurious. The collection of these remains in the British Museum, principally formed by Mr. Hawkins, is unrivalled.*

THE TRIAS; OR NEW RED SANDSTONE FORMATION.† (*Wond.* p. 533). This group of rocks consists of variegated marls, sandstones, and conglomerates, frequently of a red colour, with marine shells, crinoideans, fishes, and reptiles; marine and terrestrial plants. This series contains extensive deposits of rock-salt, and brine-springs.

This formation comprises the *Trias*, or triple group, *viz.* the *Keuper*, *Muschelkalk*, and *Upper Bunter Sandstein*, of the German geologists.

Subdivisions:—

1. Variegated red, blue, and white marls, and shales, with gypsum and beds of rock-salt. (*Marnes irisées* of the French.)
2. Variegated red and white sandstones.
3. Conglomerates formed of the detritus of the older rocks.
4. Red mottled sandstone, and marls. (*Grès-bigarré of the French.*)

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* See "Petrifactions," p. 337—367.

† Called by some geologists *Poikilitic* (variegated) group.

Obs.—To this formation belong the principal deposits in Leicestershire and other midland counties of England. Fossils are not generally abundant, but some localities yield highly interesting remains. The shelly limestone of Germany, called *Muschelkalk*, which contains the *Lily Encrinite*, &c. does not occur in England. Remains of Conifers allied to the Yew and Araucaria, are found near Coventry; and peculiar reptiles (*Labyrinthodons*) near Warwick

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Palaeozoic Epochs.

THE PERMIAN FORMATION. (*Wond.* p. 533). The separation of the strata now termed *Permian* from the *Triassic*, with which they were formerly classed, was first proposed by Sir Roderick Murchison, and is based on the fact that the fossils hitherto discovered are entirely distinct from any that occur in the Trias and subsequent formations; it is, therefore, inferred, that after the deposition of the so-called Permian strata, a complete change took place in the faunas and floras of the lands and seas, and the Trias is *at present* regarded as the dawn of a new system of organic beings.

The strata comprised in this group are variegated blue and red marls and sandstones, like those of the Triassic; magnesian or dolomitic limestones; and conglomerates more or less coloured with peroxide of iron.

Subdivisions:—

1. Red and white marls.
2. Yellow magnesian limestones, and dolomitic conglomerates of Yorkshire and Durham.
3. Marl-slate in thin layers, containing reptiles and fishes. The Keuper schiefer or copper-schist of Mansfeld.
4. Marls and variegated sandstones, sands, and clays.

Obs.—This group includes the *Lower Bunter, Zechstein*, and *Roth-liegendes*,* of the German geologists. The *Permian* comprises all the

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* Signifying *Red-dead-layer*; it is a German mining term denoting that the *copper* of the upper bed has died out; this layer not being metalliferous.

deposits that intervene between the Triassic above, and the Carboniferous below; and it is believed that this formation contains but one type of animal and vegetable life.

THE CARBONIFEROUS, or COAL FORMATION. (*Wond.* pp. 660—748). Sandstones, grits, shales, layers of ironstone, and clay, with immense beds of coal; fresh-water limestones sparingly; marine limestones abundantly.

Subdivisions:—

1. *The Coal Measures.*—Sandstones, shales, and grits, with numerous beds and seams of Coal; ironstone nodules. Land plants in profusion. Intercalations of bands of limestone with fresh-water bivalves and crustaceans in some districts; and with marine shells in others.
2. *Millstone Grit.* — Sandstones, shales, and quartzose conglomerates and grit, (*provincially*, Millstone-grit): with shales and thin seams of coal, and plants of the coal measures in some localities. The conglomerates and grits have evidently resulted from the destruction of granitic rocks.
3. *Carboniferous*, or *Mountain Limestone.*—A series, nearly 1,000 feet in thickness, of limestones and flagstones, abounding in crinoideans, corals, and marine shells and crustaceans; with layers and nodules of chert. Ores of lead, zinc, copper, barytes; fluor spar, &c. Limestones, with innumerable shells of the genera Productus, Spirifer, Goniatites, Orthocera, Bellerophon, &c. Several varieties of black, bluish grey, and variegated marbles. Coal occurs in the mountain limestone of some parts of Russia.

Obs. — The strata comprised in the carboniferous (*coal-bearing*) system, consist of sandstones more or less felspathic, and of dark bituminous shales with innumerable ferns, and other vascular cryptogamiæ, and coniferæ, &c. The uppermost group is composed of numerous alternations of coal, clay, shale, ironstone, and sandstone; the middle, of sandstones, shales, clays, and quartzose conglomerates, generally of a dull red colour; and the lowermost, of crystalline limestones with occasional layers of chert, abounding in marine shells, corals, crinoidea, and other exuviæ. These lower limestones are the principal repositories of the lead ores of Derbyshire.

THE DEVONIAN OR OLD RED FORMATION. (*Wond.* pp. 204 and 751). Conglomerates, quartzose grits, sandstones, marls,

and limestones; the prevailing colour is a dull red. Shells, corals, and ganoid fishes, of a very peculiar type. *Reptiles*, (TELERPETON; *Batrachians? Chelonians?*); the most ancient reptilian remains hitherto discovered. *Ferns, Lepidodendrons*, and other trees of the carboniferous flora; fluviatile plants with batrachian ova (?).

Subdivisions :—

1. Sandstone, quartzose conglomerates, and shale, with but few fossils.

2. Flagstones, marls, and concretionary limestones; provincially termed *corn-stones;* laminated reddish and greenish micaceous sandstones (*prov. tilestones*). Peculiar genera of fish; orthocerata, and many species of marine shells.

Obs.—The term Devonian, by which the series of strata comprehended in this formation is now generally distinguished by geologists, was first proposed by Sir R. Murchison, as being more precise than the name formerly applied to this group. In Scotland, where the formation is of vast extent, it was first characterized by its peculiar ganoid fishes (Pterichthys, Coccosteus, Cephalaspis), and will probably always there retain the original name of Old Red.* In Devonshire it is marked by the presence of shells of a character intermediate between those of the Silurian and Carboniferous systems.

The sandstones are in various states of induration, and when slaty, are employed for roofing. The red colour predominates in the marls, and is derived from peroxide of iron. The formation of these rocks has manifestly resulted from the waste of ancient slate rocks, the detritus of which is cemented together into coarse conglomerates. In South Devonshire (at Torquay, Babbicombe, &c.), beautiful coralline marbles occur in this formation.

THE SILURIAN SYSTEM. (*Wond.* p. 765). Marine limestones, sandstones, shales, and calcareous flagstones, characterized by peculiar types of corals, crinoideans, mollusks, and crustaceans, constitute this important and extensive system of rocks; the *Grauwacké*, or Transition series of the earlier geologists.

* See the charming volume of Mr. Hugh Miller, entitled "The Old Red Sandstone, or New Walks in an Old Field."

Subdivisions:—

UPPER SILURIAN.

1. *Ludlow rocks;*—slightly micaceous grey-coloured sandstones. Blue and grey argillaceous limestones. Dark-coloured shales and flagstones, with concretions of earthy limestone, containing marine shells, Orthocerata, Spirifers, and Trilobites. *Fishes.*

2. *Wenlock,* or *Dudley limestone;*—sub-crystalline blue and grey limestone, abounding in Trilobites, Crinoidea, Polyparia, Spirifers, Orthocerata, &c.

3. *Wenlock shale;*—dark grey argillaceous shale, with nodules of sandstone.

LOWER SILURIAN.

1. *Caradoc sandstone;*—shelly limestones, and finely laminated, slightly micaceous, greenish sandstones. Corals, Shells, Trilobites.

2. *Llandeilo flags and limestones.* Freestone, conglomerates, grits, and limestones. Dark-coloured flags. Beds of schist with abundance of Trilobites and shells. The lowermost beds are full of small bivalves, termed *Lingulæ.*

Obs.—The *Silurian System,* (so named by Sir R. Murchison, from the *Silures,* the ancient Britons who inhabited those parts of our island in which the geological relations of these strata were first recognised by him,) occupies the border counties of England and Wales, and spreads over a vast area of both North and South Wales, intervening between the Carboniferous series and the Cambrian or ancient slate-rocks of that country.* The strata are entirely of marine origin, and many of the beds (as the well-known Dudley or Wenlock limestone) are composed of shells, corals, crinoideans, and remains of that remarkable family of crustaceans termed *Trilobites,* cemented together by carbonate of lime. A few remains of Fishes occur: Reptiles are

* "THE SILURIAN SYSTEM, founded on Geological Researches in the Border Counties of England and Wales." In two parts, royal 4to., with map, sections, &c., by Sir R. I. Murchison, G.C. St.S. &c. In studying the beautiful map which accompanies the work, it must be borne in mind that ten years have elapsed since Sir R. Murchison abrogated the boundary line that separates the Cambrian and Silurian rocks in this chart, from the conviction that those deposits constitute but one natural system (see *Wond.* p. 803). For an account of the Silurian rocks of other countries, see "GEOLOGY OF RUSSIA," by the same Author. A summary of the characters of the Silurian System, by Sir R. Murchison, is given in *Geolog. Journal,* vol. viii. pp. 173—183.

strata of the respective formations that has determined the characters of the physical geography of England. The Alpine or mountainous districts, which extend north and south along the western portion of England and Wales, from Cornwall to Cumberland, are formed by the elevated masses of the Silurian, Cambrian, and Metamorphic rocks. These are succeeded by a band of the Carboniferous and Triassic deposits, with a few intrusions of metamorphic and plutonic rocks, that stretches from the coast of Devonshire, through the midland counties, by Leicestershire and Derbyshire, to Newcastle. On the south-east of this tract, the Oolite and Cretaceous formations, chiefly made up of argillaceous and calcareous strata, constitute a diversified agricultural district, extending from the southern shores of Hants and Dorset to the coast of Yorkshire. The Wealden occupies the country lying between the Chalk Downs of Sussex, Hants, Surrey, and Kent. The Tertiary deposits lie in basins or depressions of the upper cretaceous rocks in the south-eastern and eastern maritime districts, and on an extensive area of these beds stands the metropolis of England; lastly, irregular accumulations of Drift, containing mammalian remains in some localities, are spread over the surface of the ancient formations, and form the immediate subsoil of the most fertile regions.

CHAPTER III.

ON THE NATURE OF FOSSILS, OR ORGANIC REMAINS.

Fossils; Petrifactions.—It is very generally the case, that persons who are not conversant with the nature of organic remains, suppose that all fossils are petrifactions; and unless a specimen has the aspect and hardness of stone, they regard it as of modern origin, and devoid of interest. Hence they are surprised to find among the choicest treasures in the cabinet of the geologist, shells and corals as perfect in form, as if recently collected from the sea-shore; bones as little changed, as if they had been interred but for a short period; and teeth possessing their sharp edges and enamel unimpaired. In my early researches I fell into this error, and threw away many beautiful shells that were associated with casts of ammonites in the marl at Hamsey, supposing, from their perfect state, that they had been accidentally imbedded, and were not genuine fossils. But the state of preservation, and the degree of change which an organic body has undergone in the mineral kingdom, have no necessary relation to its antiquity. The shells in some of the ancient secondary strata are frequently as little changed as those in modern tertiary deposits. I have collected from the lowermost clays of the Wealden, fresh-water shells with traces of the epidermis, and the ligament by which the valves were held together, perfect; and bones of reptiles from the strata of Tilgate Forest, as light and porous as those of the bears and hyenas, from the Caverns of Germany. On the other hand, fossil remains from the newest tertiary

formations are often completely petrified, that is, permeated by, or transmuted into, stone.

The words *fossil* and *petrifaction* are so commonly used as synonymous terms, even by educated persons, that it is necessary to define the sense in which they are employed in these volumes.

Fossils are the durable parts of animal and vegetable structures imbedded in rocks and strata by natural causes at a remote period; thus wood in a state of lignite, bog-wood, and coal, or of siliceous or calcareous stone, is *fossil wood;* and bones or shells, whether in an earthy and decaying state, or permeated by calc-spar, flint, or iron, and converted into a hard mineral substance, are alike *fossil bones* or *shells.*

Petrifactions are the remains of animals and vegetables in which the original structure is converted into stone, or, in other words, is *petrified;* such are the silicified stems of trees from Antigua, and Germany, and the calcified bones and shells in the Oolitic and Wealden limestones. Such petrifactions may be correctly termed fossil plants, bones, or shells; but similar organic remains, though of equal antiquity, which have not undergone such changes, are not petrifactions in the proper meaning of that term.

The process by which petrifaction is effected is still involved in obscurity; mineral solutions have permeated the original tissues, and the organic molecules have been replaced by mineral molecules, but how this transmutation is produced is not understood. Mr. Dana's observations and Mr. Jeffery's experiments have, however, thrown much light on the process of silicification.*

INCRUSTATIONS.—Another prevalent error is that of considering Incrustations to be fossils or petrifactions; a mistake which is sanctioned by the custom of calling waters that are

charged with calcareous earth (*lime*), and deposit it in considerable quantity, petrifying springs; as those of Matlock, and other places in Derbyshire. (*Wond.* p. 76.) But incrustations are not petrifactions; stems and branches of trees, skulls, bones, shells, &c., are simply invested with a calcareous coating or crust, which is generally porous and friable, but often crystalline and compact. The inclosed bodies are not permeated by the stony matter; if the mass be broken, or the incrustation removed, we find the twig, or stem, either dry and shrivelled, as in the specimens, figs. 2, 3, 4, Plate III.; or tubular cavities are left by the decay and removal of the vegetable structure, as in fig. 10, Plate III.

But although incrustations be not petrifactions, natural specimens, (not the so-called petrified nests and twigs, in which the bad taste of the guardians of the Derbyshire springs is embodied, and dispersed all over England,) are objects of considerable interest, as illustrative of a process, by which important changes are effected in the mineral kingdom. Thus springs as clear and sparkling as poet ever feigned or sung, may transform beds of loose sand and gravel into rock, and porous stone into solid marble, and cover extensive tracts of country with layers of concretionary and crystalline limestone. This process is effected in the following manner. Most fresh water holds in solution a certain proportion of carbonate of lime; and changes of temperature, as well as other causes, will occasion this calcareous earth to be in part or wholly precipitated. The *fur*, as it is called, that lines a kettle or boiler which has been long in use, affords a familiar illustration of this fact. At the temperature of 60° lime is soluble in 700 times its weight of water; and if to the solution a small portion of carbonic acid be added, a carbonate of lime is formed, which is thrown down in an insoluble state. But if the carbonic acid be in such quantity as to supersaturate the lime, it is again rendered soluble in water: it is thus that carbonate of

lime, held in solution by an excess of carbonic acid, not in actual combination with the lime, but contained in the water, and acting as a menstruum, is commonly found in all waters. An absorption of carbonic acid, or a loss of that portion which exists in excess, will therefore occasion the lime to be set free, and precipitated on the foreign bodies in the water, as stones, twigs, leaves, &c.

The substance thus deposited is termed *tufa*, or travertine;* and in some parts of Italy, and of our own Island, it constitutes beds of stone of great extent, in which bones, shells, and the impressions of leaves and stems, are preserved. The stalactites and stalagmites of caverns have a similar origin; many of these caves are of incalculable antiquity, and beneath their stalagmitic floors, the bones and teeth of extinct carnivorous animals are found in vast quantities.

SILICIFICATION, or petrifaction by Silex or Flint.—Silex, or the earth of flint, is held in solution in large proportions, in certain thermal or boiling springs, which, on cooling, deposit the siliceous matter (in the same manner as the travertine is precipitated from incrusting streams) on foreign substances, and produce exquisite chalcedonic infiltrations of mosses, &c. But this operation is now only known to be in activity in the immediate neighbourhood of foci of volcanic action, as in the celebrated Geysers of Iceland (*Wond.* p. 95), and the boiling springs of the volcano of Tongariro, in New Zealand (98). We have everywhere evidence that in former periods, the petrifaction, as well as the incrustation of organic bodies by silex, was carried on to an immense extent; and, doubtless, far beneath the surface, the same operation is at the present moment in constant progress, and effecting as important changes in the consolidation of loose materials, as in the earlier geological epochs.

* *Travertine*, so called from the river *Tibur*, whose waters are loaded with calcareous earth—*Tiburtina*, Ital. *travertina*.

The various states in which silex occurs have depended on its fluidity; in quartz crystals the solution appears to have been complete; in agate and chalcedony it was in a gelatinous state, assuming a spheroidal or orbicular disposition, according to the motion given to its particles. Its condition appears also to have been modified by the influence of organic matter. In some polished slices of siliceous nodules the transition from flint to agate, chalcedony, and crystallized quartz, is beautifully shown. The curious fact, that the cavities of echinites in chalk are almost invariably filled with flint, while their crustaceous cases are changed into calc-spar, is probably, in many instances, to be attributed to the animal matter having undergone silicification; for the soft gelatinous part sare those which appear to have been most susceptible of this transmutation. In some specimens, the oyster is changed into flint, while the shell is converted into crystallized carbonate of lime. In a Trigonia from Tisbury, formerly in the cabinet of the late Miss Bennett, of Norton House, near Warminster, the body of the mollusk was completely metamorphosed into a pure chalcedony, the branchiæ or gills being as clearly defined as when the animal was recent. In specimens of wood from Australia (presented to the British Museum by Sir Thomas Mitchell), which are thoroughly permeated by silex, there are on the external surface some spots of chalcedony that have apparently originated from the exudation of the liquid silex from the interior in viscid globules filled with air, which burst, and then collapsed, and became solidified in their present form.

In silicified wood the permeation of the vegetable tissues by the mineral matter, appears to have been effected by solutions of silex of a high temperature. In some examples the mineralization is simply a replacement: the original substance has been removed atom by atom, and the silex substituted in its place.

One of the most eminent naturalists and chemists of the United States, Mr. Dana,* suggests that the reason why silica is so common a material in the constitution of fossil wood and shells, as well as in pseudo-morphic crystals,† is the ready solution of silex in water at a high temperature (a fact affirmed by Bergman‡) under great pressure, whenever an alkali is present, as is seen at the present time in many volcanic regions, and its deposition again when the water cools. A mere heated aqueous solution of silica, under high pressure, is sufficient to explain the phenomenon of the silicification of organic structures. Mr. Dana states that "a crystal of calc-spar in such a fluid being exposed to solution, from the action of the heated water alone, the silica deposits itself gradually on a reduction of temperature, and takes the place of the lime, atom by atom, as soon as set free. Every silicified fossil is an example of this pseudo-morphism; but there seems to be no union of the silica with the lime, for silicate of lime is of rare occurrence.§

I proceed to consider the various states in which the remains of animals and plants are preserved in the mineral kingdom, and shall occasionally offer suggestions for collecting and preparing specimens; but particular instructions on this head will be given in the sequel, when the different kinds of fossils are respectively considered.

* American Journal of Science for January 1845.

† Pseudo-morphic crystals are crystals moulded in the cavities left by other crystals which they have replaced. See Dr. Blum on Pseudo-morphous minerals.

‡ Bergman first determined the solubility of silex in simple water, aided by heat, and demonstrated its existence in the Geysers and other boiling springs of Iceland.—*Parkinson, Org. Rem.* vol. i. p. 324.

§ See my "Notes on a Microscopical Examination of Chalk and Flint," Annals of Natural History, August 1845.

ANIMAL REMAINS.—Of the higher orders of animals, the more durable portions of the skeleton, as the bones and teeth, are almost the only parts that occur in a fossil state; except in some remarkable instances, in which entire carcasses of extinct species of Elephant, and of Rhinoceros, have been found imbedded in solid ice, and frozen gravel. (*Wond.* p. 152.) The countries of arctic regions are now the only localities in which such phenomena are likely to be met with; it appears, however, that in some remote period, the bodies of large mammalia were transported by icebergs into temperate regions, where the ice melted, and the animals either sunk to the bottom of the sea, or were drifted into estuaries, or stranded on the shore: the soft parts then decomposed, and the skeletons and detached bones were left imbedded in the silt, sand, or shingle.

In this manner alone can be explained the occurrence of bones and teeth of the mammoth, rhinoceros, hippopotamus, &c. so common in the alluvial or drifted deposits of this country; for these relics, though extremely friable, and buried in shingle, boulders, and other transported materials, are not waterworn, but in numerous instances remain as sharp and perfect as when recent. In the ancient shingle of Brighton cliffs (*Wond.* p. 114), I have found bones and teeth of horse, deer, ox, whale, &c. impacted with quartz and granite pebbles and boulders; the bones, though crumbling to pieces if not very carefully removed, being entire, and the whole mass held together by calcareous spar, deposited by water that had, during the lapse of ages, percolated through the chalk-rubble above.

Fossil bones are found in four different states: 1. With their animal matter, as in the bones of the Mastodons from Big-bone Lick, Kentucky. 2. With the animal matter removed. 3. With the earthy matter partly removed. 4. With the animal matter carbonized, or converted into bitumen; this change is common in the blue Lias clay;

the bones retain their usual quantity of phosphate of lime, but the animal matter is converted into carbon. This alteration appears to have taken place unconnected with a high temperature, and to have been a spontaneous change in a moist situation, to which air had no access.*

Another, and very remarkable condition, is that in which the phosphate of lime has been removed by the infiltration of water charged with sulphuric or carbonic acid, and the gelatin converted into leather by tannin; as is the case with bones and teeth of deer, horses, &c. obtained from a submerged forest of oak, larch, &c. near Ferry-bridge, in Yorkshire; of which there are many instructive specimens in the York Museum.†

The cancellated structure (that is, the little cells or pores) of the long-bones of mammalia, found in caverns in England and Germany, and in the breccia of Gibraltar, and the conglomerates of Ava and the Sub-Himalaya mountains, &c., are often filled with crystallized carbonate of lime. In the Wealden deposits the osseous carapaces and plastrons of Turtles, and the bones and teeth of Crocodiles, Lizards, &c., are almost without exception heavy, and of various shades of brown or umber, from the infiltration of solutions of carbonates and oxides of iron.

In some instances, bones of a jet black are imbedded in the white calciferous grit; the phosphoric acid in the original organism having combined with iron and produced a deep blue or black phosphate of that mineral, and left the surrounding stone uncoloured.

Petrifaction by the infiltration of calcareous solutions is equally common; and the medullary cavities of the bones are frequently lined or filled with white calc-spar; brilliant pyrites also enters into the composition of these fossils, frosting over with a golden metallic deposit the cavities and fissures.

* Mr. Smee, London Med. Gazette, November 1840.

† Communicated by Professor John Phillips.

The permeation of the teeth by mineral matter, produces beautiful examples of the tissues of those organs; the dentine is often stained throughout with a rich sienna tint, and sections viewed under the microscope by transmitted light, reveal the character and distribution of the calcigerous tubes more clearly even than in recent specimens.

It is extremely rare that osseous structures are found petrified by flint; among the many thousands of bones which I have extracted from the rocks, or have seen in collections, I know but of one instance of a silicified vertebra, that of a Mosasaurus, from a chalk-pit near Brighton; and a few bones and scales of fishes. But notwithstanding the weight and apparent solidity imparted by these modes of mineralization, the substance is generally rendered extremely brittle, so that the development of the bones from the stone in which they are imbedded, and the removal of the hard ferrugino-calcareous crust investing them, is no easy task, but requires much tact, experience, and patience, to execute successfully.

Hints for collecting fossil bones.—The light, friable, porous bones, require great care in their removal from the deposit in which they are imbedded, whether it be clay, consolidated shingle, or limestone; if of considerable size, they will almost invariably break to pieces, and many examples will not admit of repair. It is therefore always desirable, before attempting to extract a large bone, to make a sketch of it; its form will thus be known, should it be destroyed; and if it crack into fragments that will admit of reunion, the drawing will be a valuable guide for the replacement of the separated parts. If only a few pieces remain, those which show any portion of the terminations, or joints, should be preserved, as they afford the most precise and important characters. The faithful record even of an imperfect and unknown fossil is not without value; and as the antiquary carefully preserves shreds of ancient

manuscripts, in the hope that other documents may one day come to light, and enable him to interpret these now unintelligible records; so the geologist should treasure up every fragment of an undetermined organic remain, for the time may arrive, as I have often experienced, when specimens will be discovered that may illustrate its nature, and prove it to be of considerable interest.

The broken porous bones may be easily repaired by a hot weak solution of glue; and when the joinings are set, the bone should be saturated with thin glue, well brushed in, and the surface be sponged clean with very hot water before the cement is congealed. When dry, the specimens will be found to possess considerable firmness and durability.* By this process the tusks of mammoths and elephants may be restored, however much crushed; time, patience, and a little dexterity, only are required, to convert a heap of mere fragments into a valuable relic of the ancient world.

When the bones are tolerably perfect, but dry and friable from the loss of their animal oil, they may be made durable by saturating them with drying oil, and exposing them to a considerable degree of heat; in this manner the magnificent skeletons of the sloth tribe, the Megatherium, and Mylodon, in the Hunterian Museum, were prepared. When a bone appears as if cracked into numerous pieces before its removal, but still preserves its form, the only method by which it can be successfully extracted, is by spreading over it a thick layer of plaster of Paris, which should be used of the consistence of cream; when it sets, (which, if the plaster be recently prepared, will be in the course of a few minutes,) the specimen may be carefully extricated, and the plaster removed or not, according to the nature of the fossil, and the parts to be displayed. The bones of the large reptiles which occur in the Wealden

* A liquid, called "Neuber's liquid glue," is an excellent cement for this purpose: it is sold at No. 54, New Oxford Street, London.

and Oolite, may be restored in the same manner. These remains are generally very brittle, and when imbedded in hard grit cannot be extracted whole: they will often fall to pieces on the slightest blow of the hammer or chisel. When of moderate size, it is best not to attempt their removal from the stone, but to trim the block into a convenient shape, and carefully chisel away the surrounding part, so as to expose the essential characters of the bone. In all cases this is an excellent method where practicable, for such specimens have a double interest; they are at once illustrative examples of the fossil, and of the rock in which it was deposited.

But many specimens will not admit of this method; and with large ones it is inconvenient and undesirable, except where bones lie in juxtaposition. The large examples in Tilgate grit, (figured in the Fossils of Tilgate Forest,) were all extracted piecemeal from the rock: and most of the gigantic bones of the Iguanodon, &c. now in the British Museum, were originally in many hundred pieces, and were cemented together with glue in the manner above described; I have found no other method so convenient and effective.

When a bone is too imperfect to be united as a whole, it may be imbedded in Roman cement, or plaster of Paris, which when dry may be coloured of the prevailing tint of the rock. For large heavy specimens, the cement is preferable; it is of easy application, and the fissures and cracks of the bones may be filled up with it, taking care first to cover the parts with thin hot glue, or the cement, when it dries, will shrink and fall out. A thin coating of mastic varnish will restore the colour, and by excluding the air, tend to preserve the specimens.

The teeth have generally undergone the same changes as the bones with which they are associated. The teeth of elephants or mammoths that are imbedded in loose calcareous earth, like the loam and chalk rubble of Brighton

cliffs, and of Walton in Essex, are friable, and apt to split and separate in the direction of the vertical plates of dentine and bone: the pieces should be glued together, and when set, the tooth be thoroughly saturated with thin glue, used very hot, and the superfluous cement removed with a sponge wrung out as dry as possible from boiling water. If there be any portion of the jaw attached to the teeth, it must be carefully preserved; and search should be made for fragments of the articulations, or parts of the joints and sockets.

In argillaceous strata, as the Lias-shale, London Clay, &c., the fossils are frequently saturated with brilliant pyrites, or sulphuret of iron; a mineral which decomposes upon exposure to the atmosphere, and occasions the destruction of the specimens. The fossils of the Isle of Sheppey are peculiarly obnoxious to this change.

The remains of vertebrated animals in the Lias, very often occur as skeletons more or less perfect, the entire configuration of the original being preserved in many instances (*Bd.* pl. 7. *Petrifactions*, p. 340). But the deposit in which they lie is generally laminated, and the shale flakes off without great care; much time, labour, and practice are therefore required, to obtain specimens of any considerable size. To the late Miss Mary Anning, of Lyme Regis, the merit is due, of having first accomplished this difficult task; Mr. Hawkins has subsequently carried the art to perfection, as may be seen in the marvellous examples of Ichthyosauri and Plesiosauri, in the British Museum.*

The small specimens, such as the detached paddles, groups of vertebræ and ribs, &c., that are likely to come under the collector's notice in his personal researches, are not difficult of preservation. Mr. Hawkins employed a strong watery solution of gum arabic as the cement, and plaster of Paris as the ground, using shallow wooden trays of well-seasoned

* Petrifactions, Room IV. chap. iv. pp. 341, 376.

wood, in which the specimens were permanently imbedded: the bones, scales, &c. were then varnished with a solution of mastic, and the ground coloured bluish grey, to imitate the Lias. I have had considerable practice in the dissection of skeletons imbedded in Lias, and having found the method previously described answer every purpose, have not employed that recommended by Mr. Hawkins.

The scales of reptiles and fishes, either in connected masses or detached, are frequently met with in great perfection, and sometimes associated with the teeth and bones. In the Lias, even the remains of the skin and integuments (*Bd.* pl. 10) have been discovered. Whenever any part of a skeleton is found lying in shale or stone, the surrounding block should therefore be carefully examined, to ascertain if there be traces of the skin or integuments, before any part is removed by the chisel. The specimen of an Ichthyosaurian paddle, figured in the second volume of this work, affords a good illustration of the propriety of this caution. Around the bones are seen the carbonized remains of the cartilaginous fringe that supported the integuments, and thus the perfect form of the paddle has been ascertained; had the surrounding stone been chiselled away, the most important characters would have been obliterated, as probably they have been in numerous instances.

Nodular masses of indurated clay containing fishes, are often broken with difficulty in such a manner as will expose the enclosed fossil, for the nodule generally splits in various directions, and the specimen is irreparably mutilated or defaced. My friend Sir Woodbine Parish informs me that by subjecting such nodules to a high temperature—but not to a red heat—and then plunging them in cold water, they may when dry, by a properly directed blow of a hammer, be readily fractured in a direction parallel with the plane of the imbedded fossil, and the fish be laid bare in the most favourable position.

The scales of fishes, and the integuments of marine reptiles, are not the only vestiges of the dermal coverings of vertebrated animals that are preserved by mineralization. Traces of the wing-integument of flying reptiles, and of the feathers of birds, are sometimes manifest: and even when every atom of the original structure has perished, the impression may remain, and afford satisfactory results. The footmarks of unknown animals are often preserved in the rocks, and the imprints of the feet of several species of bipeds, presumed to be birds of colossal size, in tracks as distinct as if but recently made, have been discovered in the New Red sandstone of North America; in the section on fossil birds, this highly interesting subject will be fully explained.

The student, even from this brief review, will perceive how many valuable facts may be unnoticed, and irretrievably lost, unless attention be paid to the various circumstances under which fossil remains are presented to his notice.

Of the invertebrated orders, the most durable, and consequently the most numerous relics, are shells and corals. The integuments of the eyes, antennæ, and wings of Insects occur; and the shelly coverings of Crustaceans are not uncommon; those of the Echinoderms, the Star-fishes, and of the Crinoidea or Lily-animals, are very abundant in certain deposits. Instructions for the collection and arrangement of these fossils will be given in the chapters in which they are severally described.

PART II.

CHAPTER IV.

FOSSIL BOTANY.

Fossil Vegetables.—The remains of the vegetable kingdom are presented to the notice of the geologist in various conditions; in some instances these relics are but little changed in their aspect, as, for example, in the recent accumulations of mud and silt, at the bottoms of lakes and rivers, and in morasses, and peat-bogs. In tufaceous incrustations, the imprints of wood, and of leaves and stems, are often sharply defined on the solid masses of concretionary and crystalline limestone.

In the ancient deposits, vegetables are found in two different states. In the one their substance is completely permeated by mineral matter; it may be calcareous (*lime*), siliceous (*flint*), ferruginous (*iron*), or pyritous (*sulphuret of iron*); and yet both the external characters, and the internal structure, may be preserved. Such are the fossil trees of the Isle of Portland, fragments of which so closely resemble decayed wood, as to deceive the casual observer, until by close examination of their texture and substance he finds that they possess the weight and hardness of stone. In the silicified wood which abounds in many of the tertiary strata, the most delicate tissues of the original are preserved, and by microscopical examination (see Pl. V.) may

be displayed in a distinct and beautiful manner. In calcareous fossil wood the structure is also retained; and in many limestones, leaves and seed-vessels are well preserved.

The ligneous coverings, or the husks and shells, of nuciferous fruits, and the cones or strobili of Firs and Pines, are frequently met with in an excellent state of preservation; in some rare instances indications of flowers have been observed (*Lign.* 67). The parts of fructification in some of the fern tribe (*Lign.* 25 and 27), occur in coal-shale, and in the grit of Tilgate Forest (*Wond.* p. 394): the pollen, and the resinous secretions of pines and firs, have been discovered in tertiary marls, and in the Greensand. The well-known substance, *Amber*, so much in request for ornaments, is unquestionably of vegetable origin; it has been found impacted in the trunks of its parent trees (*Wond.* p. 242). The *fossil resin* discovered in the London clay, at Highgate and the Isle of Sheppey, is doubtless referable to the coniferæ found in that deposit.

In the Clathrariæ of Tilgate Forest, indications of a resinous secretion have been detected.

The *Diamond*, which is pure charcoal, is probably a vegetable secretion, that has acquired a crystalline structure by electro-chemical forces. It has been converted into *Coke* and *Graphite* by the action of intense heat; and the electrical properties of the substance were changed, the Diamond being an insulator, and the Coke, a conductor of electricity. (*Wond.* p. 706.)

When the microscope is more extensively employed in investigations of this kind, it is probable that the siliceous spines and stars which begem the foliage of many plants (as the *Deutzia*, *Lithospermum officinale*, &c.), will be discovered in a fossil state, for they are as indestructible as the frustules of Diatomaceæ, and the spicules of sponges which are so common in flint and chalcedony.

But vegetables occur not only as petrified stems, leaves,

and fruits, associated with other remains in the strata, but also in beds of great thickness and extent, consisting wholly of plants transmuted, by that peculiar process which vegetable matter undergoes when excluded from atmospheric influence, and under great pressure, into *Lignite*, and *Coal*. And there are intermediate stages of this process, in which the form and structure of the trees and plants are apparent; and a gradual transition may be traced, from the peat-wood and submerged forests of modern epochs, in which leaves, fruits, and trunks of indigenous species are preserved, to those ancient accumulations of carbonaceous matter, whose vegetable origin the eye of science can alone detect.

For the collection and preservation of fossil vegetables, with the exception of those which are permeated with pyrites (as those of the Isle of Sheppey, &c.), but few instructions are required. The silicified and calcareous stems are generally easy of extraction, even when imbedded in hard stone, and if broken can be repaired with glue. When the stems bear the imprints of leaf-stalks (as in *Lign.* 31 and 54), the surrounding stone should be carefully examined, with the view of detecting impressions, or other indications of the foliage. Delicate leaves in clay, or shale, must not be washed; a thin coat of mastic varnish, or of gum water, applied with a camel-hair pencil, will preserve them, and render them more distinct. When a leaf, fruit, seed-vessel, or other fragile object is attached to clay or friable sandstone, it is advisable to glue the specimen to a piece of thin wood or pasteboard, of suitable proportions.

The Sheppey fruits and other fossils permeated with iron pyrites, generally decompose after a few months' exposure to the air. The fruits, especially, are liable to decomposition; Mr. Bowerbank keeps his specimens in bottles of water; a solution of isinglass in spirits of wine is the best varnish to preserve such fossils, without obscuring their character and injuring their appearance: but even this method is

often unavailing. The pyritified fir-cones of the Wealden decompose in like manner: I have had the misfortune to lose several unique and most instructive specimens from this cause; boiling them in linseed oil preserves them, but greatly impairs their appearance.

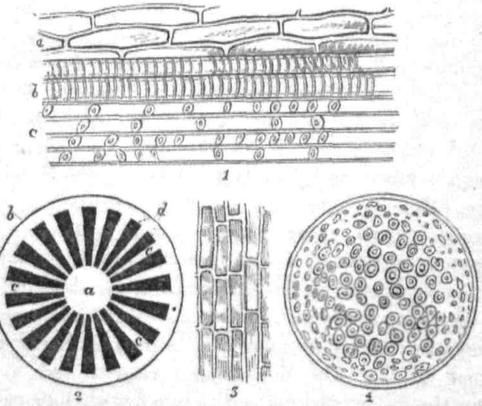
ON THE INVESTIGATION OF THE FOSSIL REMAINS OF VEGETABLES.

VEGETABLE ORGANIZATION.—As fragments of the stems, trunks, and branches, are very often the only vestiges of fossil plants, a knowledge of the characters by which the principal divisions of the vegetable kingdom may be distinguished by their internal structure, is indispensable to the successful investigation of the Flora of the ancient world. Although I have treated of this subject in the Wonders of Geology, (*Wond.* p. 694,) it will here be necessary to present the student with more ample details. The excellent introductory botanical works of Dr. Lindley, and Professor Henslow, convey full information on this, and every other department of the science, and should be consulted by those who intend to make this branch of Geology their particular study. For the general reader, and amateur collector, the following brief notice of a few obvious essential characters of vegetable organization, may perhaps afford sufficient information, to enable them to understand the principles on which the successful investigation of the nature and affinities of fossil plants must be conducted.

Every plant is essentially an aggregation of cells;* and

* "A *cell* in botanical language, means a little bag composed of membrane, and containing a living substance capable of spontaneous growth by multiplication, or division of its parts. Of such little bodies, millions of which may be contained within the space of a cubic inch, all the soft parts of vegetables are composed; in sea-weeds they are often of large size."—Dr. Harvey's Sea-side Book, with which the reader is doubtless familiar.

the most simple forms of vegetation consist of a congeries of cells (*cellular tissue*) of the same kind, and have no visible fructification; such are the sea-weeds (*algæ, confervæ*, &c.), mosses, and lichens. In the more complex tribes the cells become variously modified, are elongated into tubes or vessels (*vascular tissue*), some of which possess a spiral structure, and others have their sides studded with little glands. The vascular tissue consists of two kinds of



LIGN. 1. SECTIONS OF RECENT VEGETABLES; illustrative of their internal organization. (From *Dr. Lindley.*)

Fig. 1.—*Longitudinal Section of Coniferous Wood.*
a. The Ducts. *b.* Spiral Vessels. *c.* Glandular vessels.
2.—Transverse section of a dicotyledonous stem.
a. Pith, or central column. *b.* The bark. *c.* Medullary rays.
d. Vascular tissue between the medullary rays.
3.—Elongated cellular tissue, forming the medullary rays.
4.—Transverse section of a monocotyledonous stem.

vessels. 1. The *spiral vessels* or *tracheæ*: these are membraneous tubes, with conical extremities, having within a coil of elastic fibre spirally twisted, and capable of being unrolled (*Lign.* 1, *b.*). 2. The *ducts*; which are a modification of the structure of the spiral vessel; their extremities

are rounded or conical, and their sides marked with transverse lines, rings, or bars. Their functions appear to be different from those of the spiral vessels, and they are found in situations where the latter never occur.

The organization of the stem in the whole class of flowering plants, possesses characters so evident, as to afford the most important aid in the investigation of their fossil remains. Without dwelling on minor modifications, they are separable into two divisions, namely, the Endogenous (signifying *to grow from within*), and the Exogenous (*to grow from without*). Both possess vascular tissue, but so differently arranged in the two classes, as to constitute distinctive characters which are seldom obliterated, although what was once a flexible stem, is now a mass of flint.

ENDOGENOUS STEMS.—As the seeds of the plants belonging to this division have but one cotyledon, or *seed-lobe*, as the Lily, they are also termed monocotyledonous; the reader therefore must remember that these terms are synonymous. These stems consist of an uniform mass of cellular tissue, in which bundles of vascular or woody fibre are imbedded; a transverse section presents a surface dotted over with spots, produced by the division of these groups of vessels, pretty uniformly distributed, but more densely arranged towards the circumference (*Lign.* 1, *fig.* 4). A slice of cane affords an illustration of this structure.

The increase of these stems is effected by the formation of new cells and bundles of vessels in the central axis, which force their way among the old tissue, and occasion the condensation of the latter towards the outer edge. These plants have neither pith, concentric circles of woody fibre, nor true bark; negative characters of the highest importance in the determination of fossil stems.

EXOGENOUS STEMS.—The seeds have two cotyledons, or seed-lobes, as in the Bean, hence the plants of this class are

also called dicotyledonous. In these stems the cellular tissue forms a central column, or pith (*Lign.* 1, *fig.* 2, *a.*), and an external band, or cylinder, called the bark (*fig.* 2, *b.*); the two being connected by thin vertical plates, termed *medullary rays*, which are also formed of cells (*fig.* 2, *c, c.*); the diagram, *Lign.* 1, exhibits this arrangement. The interval between the pith and the bark, and the interspaces of the vertical radiating plates (*fig.* 2, *d.*), are filled up by woody fibre or vascular tissue, consisting of spiral and other vessels. The ligneous structure of exogenous stems consists, therefore, of a cylinder formed of wedge-shaped processes, that extend between the medullary rays to the pith, and is surrounded by the bark; a new zone of woody fibre is added annually between the bark and the former cylinder, and from this mode of increase the term *exogenous* is derived: a transverse section of a branch of oak or ash will show this structure. The rings, or concentric circles, are the annual zones of wood; the fine lines radiating from the centre, or pith, to the circumference, or bark, are the medullary rays (*Lign.* 1, *fig.* 2, *c*: see also *Plate V. fig.* 4).

The organization above described, will be found more or less manifest in fossil wood, stems, and branches. The monocotyledonous structure is beautifully displayed in the silicified stems of palms from Antigua (*Plate V. fig.* 1, 1[a].): and the dicotyledonous, in petrified trees from Egypt. The pith, medullary rays, vascular tissue, and circles of growth, are preserved in the siliceous and calcareous wood found in many parts of England.

STRUCTURE OF CONIFERÆ (*cone-bearing*).—The remains of a numerous family of dicotyledonous trees, termed *Coniferæ*, as the pine, fir, larch, &c., are so abundant in the stratified rocks, that it is necessary to describe in more detail the peculiarity of structure by which their stems and branches may be recognised. The most delicate woody tissue, as we

have above stated, consists of elongated cells or tubes, of two kinds: in the one, the membrane of which they are composed is smooth: in the other, the walls of the tubes are covered by little oval or circular bodies called glands (*Lign.* 1, *fig.* 1, *c.*). A branch of larch or pine, split longitudinally, and viewed by a powerful lens, will exhibit the appearance here described. This glandular structure is so constantly and largely developed in the coniferæ, that although it is also possessed by other aromatic trees, we shall rarely err in referring fossil wood in which this organization is apparent, to this family of vegetables (see *Plate V. figs.* 2, 3). These glands in the pines and firs, are supposed to be the cells which secrete a colourless volatile oil, that exudes in the state of turpentine.

From this general account of the vegetable structures that may be expected to occur in the mineral kingdom, the student will in some measure be prepared for the investigation of fossil trees and plants; but for the guidance of those who are wholly unacquainted with the principles on which the Natural System of Botany adopted in this work, is founded, I am induced to present the following concise view of the principal divisions of the vegetable kingdom, though it involves some repetition.

The following summary is given nearly in Dr. Lindley's own language:—

BOTANICAL PRINCIPLES.—One of the first things that strikes an inquirer into the structure of plants, is the fact, that while all species are capable of propagating their race, the mode in which this function is effected is essentially different in different cases. In most tribes of plants, flowers are produced, and these are succeeded by fruit, containing seed, which is shed, or scattered abroad, and grows into new individuals. But in certain families (the *Cryptogamia*), as Ferns, Mosses, Mushrooms, and the like, neither flowers, nor seeds properly so called, have been detected; but propaga-

tion is effected by the dispersion of grains or spores, which are usually generated in the substance of the plant, and eem to have but little analogy with true seeds. Hence the vegetable kingdom is separated into two distinct groups, namely, the *flowering* (*Phanerogamia*), and the *flowerless* (*Cryptogamia* or *Agamia*). As the former usually possess a highly developed system of spiral and other vessels, while the latter are either altogether destitute of them, or have them only in a few of the highest orders, and those in a peculiar state, the flowering plants are termed *Vasculares*, and the flowerless *Cellulares*. And as all the flowering, or vascular plants, when they form stems, increase by an extension of their ends, and a distension or enlargement of their circumference, but the flowerless or cellular plants form their stems simply by the addition of new matter to their points, the latter are called *Acrogens*, signifying increase from the summit.

Flowering plants are also for the most part furnished with respiratory or breathing organs (*stomata*), of which the flowerless vegetables are to a great extent destitute.

The flowering or vascular plants are also divisible into two well marked groups, namely, the *Exogens*, or *Dicotyledons*, and the *Endogens*, or *Monocotyledons*.

The EXOGENS (growing from without), increase by the addition of new woody matter to the outside of the stems beneath the bark; and they are further characterized by the embryo having two or more cotyledons, or seed-lobes, hence they are also called *Dicotyledons*; such as the Elm, Beech, &c.

The ENDOGENS, as we have previously stated, increase by the addition of ligneous matter to the inside of their stems near the centre; and as the embryo in this class has but one cotyledon, they are likewise termed *monocotyledons*, as the Cane, Palm, &c. Again, exogenous plants have the young external wood connected with a central pith, by medullary

processes; while endogens do not possess such a structure, having no central pith. In exogens the veins (venation) of the leaves, are disposed in meshes, like net-work, but in endogens the veins run parallel to each other.

The number of parts in the flower of an exogenous plant is usually five, or its multiples: in the endogens it is commonly three, or its multiples. In the germination, the young root of exogens is a mere extension of the radicle; but in endogens it is protruded from within.

Thus, in the flowering or vascular plants, we have two groups distinct from each other in their germination, the structure of their stems and leaves, their mode of growth, the arrangement of the parts of the flower, and in the structure of the embryo.

The vegetable kingdom is thus separated into three natural classes,—1, the *Exogens*, 2, the *Endogens*, 3, the *Acrogens*; but there are likewise other divisions, a knowledge of which is of great importance in the study of fossil botany; the sub-class termed GYMNOSPERMS especially requires notice.

In the strictly exogenous and endogenous plants, the fertilizing principle is communicated to the young seeds through the medium of a *stigma* and *style*, that terminate the case or pericarp in which the seeds are enclosed: but in another important group of the vegetable kingdom, the pollen is directly applied to the ovule, without the intervention of any pericarpial apparatus; hence these are termed *Gymnosperms*, signifying naked seeds. These plants have the same relation to the other exogens, as frogs and analogous reptiles bear to the other orders of their Class; they comprise the two natural orders *Coniferæ*, and *Cycadaceæ*.

The Gymnosperms also possess peculiarities of a subordinate nature: thus, many kinds have more than two cotyledons, and are therefore termed *polycotyledons*; again, the radicle usually adheres to the albumen in which the

embryo lies, hence they are sometimes named *Synorhiza*. The veins of the leaves (in those whose leaves are veined), are either simple or forked; in which respect they approach the endogens on the one hand, and the acrogens on the other.

This concise definition of the natural divisions of the vegetable kingdom will enable the reader to comprehend the botanical principles which must guide him in his attempt to explore the ancient floras, whose fossil remains are generally found in a very fragmentary condition.

I need only add that M. Ad. Bronginart, in his great work on Fossil Plants, arranges the vegetable kingdom into five classes, viz. :—

1. Cellular Cryptogamia,* or Amphigens.
2. Vascular Cryptogamia,† or Acrogens.
3. Monocotyledons.‡
4. Gymnospermous Dicotyledons.§
5. Angiospermous Dicotyledons.||

ON THE MODE OF INVESTIGATING FOSSIL REMAINS OF VEGETABLES.

The distinguished authors of the British Fossil Flora justly remark, that a few isolated, and very imperfect data, exclusively afforded by the remains of the organs of vegetation, are but too often the sole guide to the class, order, or

* Plants having the fructification concealed, and of cellular structure only.

† Plants having the fructification concealed, and with vessels, or vascular tissue.

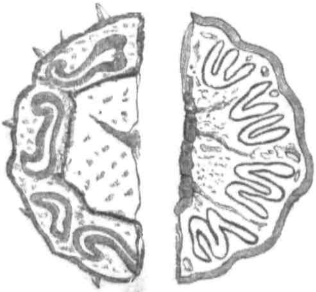
‡ Flowering plants with one cotyledon; the Endogens.

§ Plants with naked seeds; that is, destitute of a pericarp or case.

|| Plants with the seeds in a receptacle or pericarp, with a style and stigma.

genus of the fossil plants which the geologist has to examine; hence, in most instances, a general idea only can be obtained of the nature of the original.* To facilitate the study of Fossil Botany they offer some practical suggestions, which have served as the basis of the following directions for the investigation of vegetable remains, and which the previous remarks will, we trust, render intelligible.

1. *The Trunk, or Stem.*—Examine if the wood in a transverse section be disposed in concentric circles (as *Plate V. fig.* 4): if so, it belonged to an exogenous tree: if, on the contrary, the wood appears deposited irregularly in spots (*Lign.* 1, *fig.* 4), then the original was endogenous. If a transverse section show remains of sinuous, unconnected layers, resembling



LIGN. 2. SECTIONS OF FERN-STEMS.

Transverse sections (half the diameter) of two stems of recent Arborescent Ferns, to show the zone of woody fibre disposed in arcs. This structure is seen in the silicified trunks from Chemnitz.

arcs with their ends directed outwards, and of a solid structure, and imbedded among looser tissue, then it belonged to an arborescent fern; see the subjoined figures (*Lign.* 2).

If the stem be in a state of preservation that will admit of the slicing or chipping off a piece for microscopical inves-

* Foss. Flor. vol. I. p. xxvi.

tigation, the process described at the conclusion of this section should be employed.

The following data may be thus obtained. If the structure be entirely cellular, and it can be satisfactorily ascertained that it never possessed vascular tissue, the original belonged to the *Cryptogamia; i. e.* to fuci, mosses, and the like.

If it consist of parallel tubes, and has neither pith, nor rays passing from the centre to the circumference, the tree or plant was *endogenous*, like the Palm. If any trace be present of tissue crossing the longitudinal tubes at right angles, and radiating from the centre to the circumference, this will prove the existence of medullary rays, and the original must have been *exogenous*, as the Oak, Elm, &c.: and if in a transverse section the tubes appear of equal size, the tree was probably *coniferous*, or *cycadeous* (*i.e.* related to the plants called *Cycas* and *Zamia*); but if larger tubes appear among the smaller ones, disposed in a definite manner (see *Plate V. fig.* 4), it belonged to some other tribe of exogenous plants.

If the walls of the tubes be studded with glands (*Lign.* 1, *fig.* 1, *c; Plate V. figs.* 2[b.] 3[b.]), the fossil belongs to the Coniferæ.

If any vestige of a central pith be discovered, the exogenous nature of the original is undoubted, for no other class, as we previously stated, possesses a central cellular column.

The absence or presence of a true cortical investment, or bark, is important, for a distinct bark is the characteristic of the *exogenous* class:* a cortical integument, or rind, not separable from the enclosed structure, indicates the *monoco-*

* An apparent exception to this rule is found in the fossil genus *Clathraria*, described hereafter, which has a distinct hollow cortical cylinder, that separates from the internal axis: *this is not true bark*, but is formed by the consolidation of the bases of the petioles or leaf-stalks; see *Lign.* 54.

tyledons; and the entire absence of any rind, the *cryptogamia.*

The markings on the stems, occasioned by the scars or cicatrices left by the separation of the petioles or leaf-stalks (as on the stalk of a cabbage), afford important evidence, since they are commonly present, even when the cylindrical trunk is compressed into a flat thin layer of coal; as we shall often have occasion to remark. In this place it need only be stated, that by these scars may be detected the position of the leaves, and the form of the bases of the petioles or leaf-stalks; their probable direction, whether they were opposite, alternate, verticillate or spirally disposed, deciduous or persistent, imbricated or remote. Even when no traces of the leaves remain, the origin of the branches, and their bifurcation, may perhaps be determinable.

2. *The Leaves.*—In a fossil state the texture and surface of the leaves are sometimes preserved; but in general the outline of the leaf, its division and arrangement, and its mode of venation, can alone be ascertained. The *venation,* that is, the form and distribution of the vascular tissue, or vessels, through the leaf, is the most important character for our guidance; and Dr. Lindley offers the following suggestions on this point. If the veins be all parallel, not branched, or only connected by little transverse bars, and the leaves undivided (as in the Lily or Hyacinth), the plant was probably endogenous; but if the leaf be divided or pinnated, it may be referable to Cycadeæ (*Lign.* 45).

Leaves having the veins of equal, or nearly equal thickness, and dichotomous (*forked*), or very fine, and simply divided, belong to the fern tribe; to this division an immense proportion of the foliage found in the carboniferous strata is referable; the genera of fossil ferns have been constructed principally from the venation.

If the veins of a leaf be obviously of unequal thickness, and reticulated, or disposed in net-like meshes, as in the

rose and apple, the original was dicotyledonous (*Plate III. figs.* 4, 8).

Leaves of a large size, destitute of veins, and irregularly divided, probably belong to fuci, or other marine plants (*Lign.* 10).

Such are the rules for the investigation and interpretation of the characters of stems and foliage, which have been preserved by mineralization. Their application is not difficult, and the student may by their assistance obtain some general indications as to the nature of the original trees or plants, whose petrified remains form the subject of his examination.

ON THE MICROSCOPICAL EXAMINATION OF FOSSIL VEGETABLES.

Mr. Nicol, who first suggested the method now generally adopted for preparing fossil wood, coal, &c. for microscopical examination, and which was employed by Mr. Witham in the illustrations of his beautiful work on the structure of fossil plants,* has so clearly explained the process, that by a little practice the student will be able to prepare specimens sufficiently thin for every useful purpose. Several lapidaries in London, (see list at the end of this work,) polish and mount fossil vegetables and other substances, in a very superior manner; but their charges are high, and they frequently injure specimens by grinding them too thin, and thus obliterating structure. I would recommend that a small chip of the specimen, if possible in a *radial* direction, should be examined by reflected light, always beginning with the lowest object-glass and eye-piece, and ascending to the highest power; at first without any preparation;† subsequently the object should be immersed in oil of turpentine,

* Observations on Fossil Vegetables. 4to. 1833.

† The drawings in *Plate V. figs.* 2 and 3, of fossil coniferous wood, were from chips seen by reflected light, and without any preparation.

which will render it somewhat transparent, and it then should be examined by transmitted light. By this exploration we may detect structure, and ascertain if the specimen be worth the trouble or expense of further preparation.

Coal may be prepared for examination, by removing with a sharp knife a thin pellicle, or a minute scraping; immerse it in a drop of oil of turpentine on a piece of glass; then add a little Canada balsam, and hold the glass over the flame of a lamp till the balsam is spread evenly over the specimen. But without any preparation, the surface of coal recently broken may be successfully investigated. One of the most interesting examples of coniferous structure in coal that my cabinet contains, was discovered by my son in a piece lying on the fire, which had been cracked by the heat; and I have another fragment, showing the spiral vessels, and coniferous glands, which the Rev. J. B. Reade obtained under similar circumstances. But for choice specimens, the following method is to be employed; and in many cases no other plan will succeed. Sections of teeth, bone, marble, &c. may be prepared by a like process.

MODE OF PREPARING SLICES OF FOSSIL WOOD FOR MICROSCOPICAL EXAMINATION.

"Let a thin slice be cut off from the fossil wood, in a direction perpendicular to the length of its fibres—the slice thus obtained must be ground perfectly flat, and polished. The polished surface is then to be cemented to a piece of plate glass (3 in. long and 1 in. wide) by Canada balsam—a thin layer of balsam must be applied to the polished surface of the slice, and also to one side of the glass—the slice and the glass are now to be laid on any thin plate of metal, and gradually heated over a slow fire, or a spirit lamp, to concentrate the balsam. The heat must not be so great as to throw the balsam into a state of ebullition; for if air

bubbles be formed, it is difficult to get rid of them, and if not removed they will prevent the complete adhesion of the two surfaces when applied to each other; the heat of the metal should never be so great that the fingers may not be held in contact with it for a few seconds without inconvenience. When air bubbles are formed, they should be displaced by a small piece of wood tapering to a point; when the balsam is thought to be sufficiently concentrated, and all the air bubbles have disappeared, the slice and glass may be taken from the heated metal, and pressed closely together; a slight degree of pressure will suffice to expel the superabundant balsam, and this will be facilitated by gently sliding the specimen to and fro on the glass; by this kind of motion any air that may have got entangled when the two surfaces were brought in contact, will also be removed. When the whole is cooled down to the temperature of the air, and the balsam has become solid, that part which adheres to the surface of the glass surrounding the slice should be scraped off with the point of a penknife; and by this operation, it will at once be seen whether the balsam has undergone the requisite concentration; for if it flakes off before the knife, it will be found that the slice and glass will cohere so firmly, that in the subsequent grinding, there will be no risk of their separating from each other; but if the balsam has not been sufficiently concentrated, it will slide before the knife, and in that case the two bodies will not adhere with requisite firmness. If the layer of balsam applied to the two surfaces be not too thick, its due concentration will be accomplished in four or five minutes, provided the application of the heat be properly regulated. The slice must now be ground to that degree of thinness which will permit its structure to be seen by the help of a microscope. This will be accomplished by rubbing the slice, by a rapid circular motion with the hand, on a piece of sheet lead, supplied with a little emery (*size No.* 1.) moistened with water;

when the emery ceases to act, the muddy matter remaining should be removed, and a fresh portion of emery applied; this must be repeated until the surface of the slice is perfectly flat; a sheet of copper must then be substituted for the lead, and the fossil ground as smooth as possible by flower of emery, freed from its coarser parts. The surface may then be polished by friction, with *crocus* or rotten stone, on a transverse section of any soft wood."*

Mr. Witham, Observations on Fossil Vegetables.

CHAPTER V.

ON PEAT-WOOD, LIGNITE, AND COAL.

1 2 3 4

LIGN. 3. NODULE OF IRONSTONE INCLOSING A FERN-LEAF.
Coalbrook Dale.

Fig. 1.—The nodule in its natural state.
2, 3.—The same, split open longitudinally. The leaf remains attached to fig. 2, and the impression of its upper surface is seen on fig. 3.
4.—Outline of the form of the leaf, which is a species of Pecopteris.

BEFORE entering upon the examination of the specific and generic characters of fossil plants, and the natural relations of the extinct forms with those of the existing Floras, it will be requisite to notice those vast beds of vegetable matter, in various states of carbonization, which occur in the palæozoic, secondary, and tertiary formations.

SUBMERGED FORESTS. PEAT.—The phenomenon of extensive tracts of marsh-land, with layers of prostrate trees of all ages, lying but a few feet beneath the common alluvial soil, is of frequent occurrence, both inland, and in many places along the shores of our island. (*Geol. S. E.* p. 18). These submerged forests are generally situated below the level of the sea, and afford unquestionable proof of subsidences of the land. The trees are of the kinds indigenous to the districts in which they occur; and leaves and seeds of the hazel, beech, elm, &c. are often preserved in the silt in which the prostrate forests are imbedded. On the Sussex coast there are accumulations of this kind, at Bexhill, Pevensey levels, Felpham, &c.

The extensive subterranean forests exposed in the Fens of Lincolnshire by the operations carried on for draining that district, must be familiar to those who travel by the Great Northern Railway: the protruding upright stems, broken off at a short distance above the primitive soil, will remind the geological observer of the petrified forest of the Isle of Portland.

The wood in these cases has undergone no change but that of being dyed black, by an impregnation of solutions of iron; and many trunks are in so sound a state as to be employed in building. The oak timbers of the Royal George, lately raised up from off Portsmouth, after being immersed in silt about sixty years, closely resemble in colour and texture the wood of the submerged forests. Skeletons of deer, horse, swine, &c. are occasionally found imbedded in these subterranean accumulations of vegetable remains; and sometimes canoes, formed of the trunk of an oak, constructed by the aboriginal inhabitants of Britain, with stone implements called *celts*, are met with at considerable depths.

In the peat bogs of Ireland (*Wond.* p. 66), large forest trees often occur, together with the skeletons of the elk, deer, and other animals of the chase; and in a few instances

the bodies of the primitive hunters, wrapped in skins, have been discovered.

In Belfast Lough, a bed of peat is situated beneath the ordinary level of the waters, but is generally left bare at the ebb tides. Trunks and branches of trees, with vast quantities of hazel nuts, are imbedded in the peat; the whole being covered by layers of sand, and blue clay, or silt. In most cases the pericarps of the nuts are empty, the kernels having perished; but on the eastern side of the Lough, which is bounded by limestone rocks, they contain calc-spar, which in some examples forms a lining of delicate crystals (*Plate V. fig.* 6); while in others the kernel is transmuted into calcareous spar (see *Plate III. fig.* 7); but the pericarps are unchanged, and in the state of common dried nut-shells; the water which deposited the spar in their cavities not having left a particle of mineral matter in the ligneous substance through which it had filtrated.

In a subterranean forest at Ferry-bridge, Yorkshire, hazel nuts in a similar mineralized state occur, and the branches and stems of the trees have undergone a like change; the central ligneous axis is petrified, while the outer zones have undergone no lapidification, but remain in the state of dry rotten wood.*

LIGNITE, BROWN COAL, or CANNEL COAL; these are terms employed to designate certain varieties of carbonized wood, in which the ligneous structure is more or less distinctly preserved. *Lignite* may be regarded as an imperfect coal, for in its chemical properties it holds an intermediate place between peat and bituminous coal. It is for the most part found in tertiary formations, but is not unfrequent in ancient secondary deposits, and may occur in the earliest sedimentary rocks which contain vegetable remains.

The newer deposits of *Brown or wood-coal*, are commonly

* Specimens are preserved in the Museum at York.

situated in depressions or basins, as if they had been produced by the submergence of woods and forests, in a swamp or morass; and in many instances the ligneous structure is distinct in one part of the bed, while in another the mass is a pure black coal, differing in no respect from true coal, except that it is less dense.

Bovey Coal.—One of the most instructive deposits of brown coal in England, is that of Bovey Heathfield, near Chudleigh in Devonshire, which is of considerable thickness and extent, and presents all the characters of a true coal-field; namely, beds of carbonized vegetables, alternating with layers of clay and marl. The Bovey coal is in the state of bituminized wood, the vascular tissue (which is coniferous in the specimens that have come under my notice) being apparent. It is easily chipped or split, and leaves a considerable quantity of white ashes after combustion. The layers of coal vary in thickness from one foot to three feet; and there are eighteen or twenty in a depth of about 120 feet; this coal-field extends seven or eight miles. No leaves or fruits have been discovered; bitumen occurs both in the coal and in the intermediate clays. Calcareous spar, and iron pyrites, prevail in many of the strata. In some places this brown coal is covered by a bed of peat, in which trunks and cones of firs are imbedded. The whole series appears to have been a lacustrine deposit; probably formed in a lake, into whose basin rafts of pine forests were drifted by periodical land-floods. (*Org. Rem.* I. p. 327).

The brown-coal formations on the banks of the Rhine, present the same phenomena on a more extended scale, and complicated with changes induced by volcanic action. In Iceland, where at the present time forests are unknown, there are extensive deposits of lignite of a peculiar kind, termed *surturbrand.*

Jet.—The beautiful substance called *Jet,* is a compact

lignite, and the vascular tissue may be detected even in the most solid masses; when prepared in very thin slices, it appears of a rich brown colour by transmitted light, and the woody texture is visible to the naked eye. Jet is found in great purity and abundance in the cliffs of alum-shale on the Yorkshire coast, which were celebrated in the early centuries for the production of this substance. At Whitby and Scarborough extensive manufactories of ornaments and trinkets of jet are established. The sandstone cliffs near Whitby contain masses of a very compact variety, locally termed stone-jet. In the front of the cliff, on the north-west side of Haiburn Wyke, the stump of a tree was observed in an erect position, about three feet high, and fifteen inches in diameter; the roots traversed a bed of shale, and were in the state of coarse jet, but the trunk, which extended into the sandstone, was in part silicified, while other portions were decayed and had a sooty aspect.*

Thin seams and layers, and nodular masses, as well as regular coal-fields of lignite, occur in the tertiary formations. At Castle Hill, near Newhaven, in Sussex (*Wond.* p. 239), a seam of lignite resembling the surturbrand of Iceland, a few inches thick, is interposed between strata of red marl in which are carbonized leaves of dicotyledonous trees.

At Alum Bay in the Isle of Wight, a layer of lignite occurs between the beds of vertical gravel and sand of that interesting locality.

Wealden Coal.—The Wealden formation, in some districts, contains layers of lignite, which alternate with finely laminated micaceous sandstones, marls, and clays, abounding in minute carbonized fragments of fern-leaves, with fresh-water shells, and entomostracous crustaceans. This series of strata so strikingly resembles in its general

* Geological Survey of the Yorkshire Coast; by Rev. G. Young; 1828; p. 197.

aspect the characters of a coal-field, that some years since extensive works were undertaken in Sussex, in the expectation that coal might be obtained of suitable quality for economical purposes. The search was unsuccessful, but the attempt deserves not the censure that was bestowed upon it, in the infancy of geological science;* for experience has since shown, that although the true coal-measures are only found beneath the Triassic and Permian formations, good combustible bituminous coal is not necessarily restricted to any period or series of strata, but may occur wherever the local conditions were favourable to the accumulation and bituminization of vegetable matter. In fact, the coal-fields of the north of Germany are of the Wealden epoch; and this coal more closely approaches in its chemical characters the black-coal of the ancient carboniferous formations, than any of the lignites and brown-coals of the tertiary strata. Some of the beds are highly bituminous, especially those of Schaumberg, and of the principality of Bückeburg, which may rank with the best English Newcastle coal; but those layers which are derived from coniferous trees and plants are more laminated, and somewhat resemble the brown-coal. These deposits have originated for the most part from carbonized conifers and cycads, with a few ferns and lycopodiaceæ, or club-mosses.

The brown-coal of Hohen-Warte by the Osterweld, is chiefly formed of the *Abies Linkii*, and *Pterophyllum Lyellianum*, whose leaves and twigs, closely impacted together, are generally of a brownish colour, have a glossy surface, and, when soaked in water, are perfectly flexible. The other modification of Wealden coal appears to have undergone a greater degree of pressure, and of exclusion from the atmosphere; no ligneous structure is apparent, but indistinct impressions of leaves are perceptible, and these are chiefly of ferns and club-mosses. This coal has

* See Sir J. F. W. Herschel's Discourse on *Nat. Phil.*

probably resulted from an accumulation of plants of less firm texture, and more perishable, than those of which the former is composed.*

Many interesting facts relating to the carbonization of vegetables, came under my observation during my researches in the Wealden strata; and it is a subject of regret to me, that circumstances prevented my following up the investigation of those still imperfectly explored deposits. Small nodular portions of coal, in which no structure is apparent, often occur in the calciferous grit of Tilgate Forest; and sometimes large masses of lignite, fissured in every direction, and having the interstices filled with white calcareous spar.† Some of the sandstones are discoloured by the abundance of minute particles of lignite, produced by the disintegration of ferns peculiar to the country of the Iguanodon.

The original structure and composition of a plant doubtless affected its carbonization; for in the same layer of stone, the stems of *Endogenites*, hereafter described, invariably possess a thick, outer crust, of coal; while those of *Clathrariæ*, plants allied to the Cycads, have not a particle of carbonaceous matter, but are surrounded by a reddish brown earthy substance. The nature of the stratum in which the plants were imbedded, must also have influenced the process of bituminization. Masses of vegetables buried beneath beds of tenacious clay, by which the escape of the gaseous elements set free by decomposition was prevented, must have been placed under the most favourable conditions for their conversion into lignite and coal.

That the production of lignite is still going on there can be no doubt; and the following instance of a bed of recent origin, affords an instructive illustration of the subject.

* See Dr. Dunker's Mon. Norddeutch. Weald.

† A fine specimen of this kind is in the British Museum.

Near Limerick, in the district of Maine, one of the States of North America, there are peat bogs of considerable extent, in which a substance similar to *cannel coal* is found at the depth of three or four feet from the surface, amidst the remains of rotten logs of wood, and *beaver-sticks* :* the peat is twenty feet thick, and rests upon white sand. This coal was discovered on digging a ditch to drain a portion of the bog, for the purpose of obtaining peat for manure. The substance is a true bituminous coal, containing more bitumen than is found in any other variety.† Polished sections of the compact masses exhibit the peculiar structure of coniferous trees, and prove that the coal was derived from a species allied to the American fir.

COAL.—We proceed to the examination of that remarkable substance which has resulted from the perfect bituminization of the vegetables of the most ancient Flora which geological researches have brought to light, and to which the term *Coal* is commonly restricted.

Although Balthazar Klein in the sixteenth century affirmed that coal owed its formation to wood and other vegetable substances,‡ yet I can well remember when many eminent geologists were sceptical on this point; and the truth in this, as in most other questions of natural philosophy, was established with difficulty. The experiments and observations of the late Dr. Macculloch, mainly contributed to solve the problem as to the vegetable nature of this substance; and that eminent chemist and geologist successfully traced the transition of vegetable matter from

* Pieces of wood fashioned by the beavers for the construction of their dams.

† An analysis of 100 grains gave the following results:—Bitumen 72; carbon, 21; oxide of iron, 4; silica, 1; oxide of manganese, 2; = 100.

‡ Sternberg's "Flore du Monde Primitif."

peat-wood, brown-coal, lignite, and jet, to coal, anthracite, graphite, and plumbago. Nor must the meritorious labours of that accomplished naturalist, and excellent man, the late Mr. Parkinson, author of the "*Organic Remains of a Former World*," in this field of research, be forgotten.* The first volume of that work, which treats on fossil plants, contains much original information on the transmutation of vegetables into the various mineral substances in which the nature and original structure of the originals are altogether changed and obliterated; it may still be consulted by the student with advantage.

Although the vegetable origin of all coal will not admit of question, yet evidence of the internal organization of the plants of which it is composed, is not always attainable; for the most perfect coal has undergone a complete liquefaction, and if any portions of the structure remain, they appear under the microscope as if imbedded in a pure bituminous mass. The slaty coal generally preserves traces of cellular or vascular tissue, and the spiral vessels, and the dotted cells of coniferous trees, may readily be detected in chips or slices, prepared in the manner previously pointed out (*ante*, p. 66). In many examples the cells are filled with an amber-coloured resinous substance; in others the organization is so well preserved, that on the exposed surface of a piece of coal cracked by exposure to heat, the vascular tissue, spiral vessels, and cells studded with glands, may be detected. Even in the white ashes left after combustion, traces of the spiral vessels are often discernible under a highly magnifying power. Some beds of coal are wholly composed of minute leaves and disintegrated foliage; and if a mass recently extracted from the mine be split asunder, the surface is seen to be covered with flexible pellicles of carbonized leaves and fibres, matted together; and flake after flake may be peeled off through a thickness

* See my "Pictorial Atlas of Organic Remains," 1850.

of many inches, and the same structure be apparent. Rarely are any large trunks or branches observable in the coal; the appearance of many beds being that of a deposit of foliage, shed and accumulated in a forest, (as may be observable in existing pine-districts,) and consolidated by pressure, while undergoing that peculiar change by which vegetable matter is converted into a carbonaceous mass.

In fine, a gradual transition may be traced from the peat-wood and submerged forests of modern times, in which leaves, fruits, and trunks of indigenous trees and plants are preserved, to those vast deposits of mineral coal, formed by the bituminization of the extinct Floras which flourished in the palæozoic ages.

The geological position of the ancient coal, the manner in which it is interstratified with layers of clay, shale, micaceous sandstone, grit, and ironstone—in some districts associated with beds of fresh-water shells (*Sil. Syst.* p. 84),—in others alternating with strata containing marine remains,—are fully treated of in *Wond.* pp. 729—733, and *Bd.* p. 525; and it is not within the scope of the present work to dwell in detail upon what may be termed the physical geology of the carboniferous deposits. But a few observations on the phenomena presented by these accumulations of bituminized vegetables and their associated strata, are necessary to render the subsequent remarks on the habits and affinities of the plants composing the palæozoic Flora intelligible to the general reader.

While the essential conditions for the conversion of vegetable substances into coal appear to be the imbedding of large quantities of recent trees and plants in a deposit which shall exclude the air, and prevent the escape of the gaseous elements when released by decomposition from their organic combination, so, according to the more or less perfect manner in which these conditions are fulfilled, will result coal, jet, lignite, brown-coal, or peat-wood; or a mass of partially

carbonized vegetables, like that observable when new-mown hay undergoes spontaneous combustion, from bituminous fermentation in the atmosphere (*Wond.* p. 701. *Org. Rem.* I. p. 181).

The manner in which the carboniferous strata have been deposited, has been a subject of much discussion. Some contend that the coal-measures were originally in the state of peat-bogs, and that the successive layers were formed by the subsidences of forests which grew on the sites now occupied by their carbonized remains; others suppose that the vegetable matter originated from rafts, like those of the Mississippi, which floated out to sea, and became engulfed; while many affirm that the coal-measures were accumulated in inland seas or lakes, the successive beds of vegetable matter being supplied by periodical land-floods; and the supporters of each hypothesis bring numerous facts in corroboration of their respective opinions. There can, I think, be no doubt that the production of coal has taken place under each of these conditions, and that at different periods, and in various localities, all these causes have been in operation; in some instances singly, in others in combination. Coal may have been formed at the bottom of fresh-water lakes, as in those instances where it is associated with fresh-water shells and crustaceans, as at Burdie House (*Wond.* p. 693), and in some of the Derbyshire and Yorkshire deposits; in the beds of rivers and estuaries, as in the Wealden, and in the Shrewsbury coal-field;* and from drifted forests, like the rafts of the American rivers, transported into the sea, and engulfed in the abyss of the ocean;† and the remains of

* In this coal-field are beds of limestone several feet thick, abounding in *cyprides*, fresh-water mollusks, &c.—*Sil. Syst.* p. 84.

† The immense thickness of some coal-beds, without any intercalations of earthy materials, seems to be inexplicable on any other supposition but that of accumulations of drift-wood and plants. In the Great Exhibition of 1851, there was exhibited, on the outside of

terrestrial, lacustrine, and marine animals, may accordingly be found associated with it.* But though many coal-fields (or basins, as they are termed, because they occupy depressions) have evidently been produced by different, and local agencies, the sedimentary deposits and coal-beds comprised in the carboniferous formations, setting aside unimportant variations, present a remarkable uniformity of character in their nature and arrangement, not only throughout Great Britain and Europe, but in every other part of the known world.

STRATIFICATION OF A COAL-FIELD.—The group of strata constituting a coal-field consists of an alternation of layers of coal and of clay, of variable thickness, resting, very generally, on grit, or marine limestone abounding in shells, corals, and crinoidea.

My late excellent friend, Mr. Bakewell, used to exemplify the manner in which the beds of coal are interstratified with layers of clay and shale, by the following apt illustration; let a series of mussel-shells be placed one within the other, and a layer of clay be interposed between each; the shells will represent the beds of coal, and the partitions of clay the earthy strata intercalated between the carboniferous layers; now, if one side of the series of shells be raised to indicate the general rise of the strata in that direction, and the whole be dislocated by partial cracks and fissures, the general arrangement and subsequent displacement of the beds will be represented.

The principal feature which arrests attention on the

the west end of the Crystal Palace, a section of the lowest bed of coal from Tividale Colliery in South Staffordshire, the total thickness of which was 29 feet, with no intermixture whatever of sediment, except some thin shaly partings: the entire mass was composed of carbonized vegetables.

* Sir R. I. Murchison has treated this subject with great ability: see *Sil. Syst.* chap. xi., and the illustrative maps opposite, p. 152.

examination of the section of a coal-pit, is the *uniform presence of a thick bed of clay beneath every layer of coal;* but a still more extraordinary fact remains to be mentioned, namely, that a common plant of the coal strata, called *Stigmaria*, (hereafter described, see *Lign.* 36, 38,) *invariably occurs, more or less abundantly, in this bed of under-clay,* although very rarely to be met with in the coal or shale above. This phenomenon, long since noticed by Martin, Macculloch, and other authors, but whose value was not duly estimated till the recent observations of Mr. Logan, (*Geol. Proc.* vol. iii. p. 275,) is also found to prevail throughout the Welsh coal formation, which is upwards of twelve thousand feet in thickness, and contains more than sixty beds of coal, and as many of clay with stigmariæ; the Appalachian coal-measures of the United States present the same characters.* To place this fact before the student in a clear point of view, I will describe one of the triple series of beds which compose a coal-field.

1. *Under-clay;* the lowermost stratum. A tough argillaceous substance, which upon drying becomes a grey friable earth: it is occasionally black, from the presence of carbonaceous matter. It contains innumerable stems of *stigmariæ*, which are generally of considerable length, and have their rootlets or fibres (see *Lign.* 38) attached, and extending in every direction through the clay: these stems commonly lie parallel with the planes of the bed, and nearer to the *top than to the bottom.*

2. *Coal.* A carbonized mass, in which the external forms of the plants and trees composing it are obliterated, but the internal structure remains; large trunks or stems, and leaves, are rarely distinguishable in it, but the presence of coniferous wood in many beds of coal, proves that this

* See Prof. Rogers, in the Proceedings of the American Geologists, p. 453; and Sir C. Lyell's Travels in America

arises, not from the absence of trees, but from their external forms having been obliterated.

3. *The Roof*, or upper bed. This generally consists of slaty clay, abounding in leaves, trunks, stems, branches, and fruits, and contains layers and nodules of ironstone, inclosing leaves, insects, crustaceans, &c.

In some localities beds of fresh-water mussels, and in others of marine shells, are intercalated; layers of shale, finely laminated clay, micaceous sand and grit, and pebbles of limestone, granite, sandstone, and other rocks, are often present. The most illustrative examples of the foliage of the carboniferous flora are found in this deposit, which appears to be an accumulation of drifted materials derived from other rocks, and promiscuously intermingled with the dense foliage and stems of a prostrate forest; the whole having been transported from a distance by a powerful current or flood.

Thus we have, in the first place, spread uniformly over the bottom, and constituting the bed on which the coal reposes, a stratum of clay (*Under-clay*), composed of fine pulverulent materials, which may have once constituted the soil of a vast plain or savannah; the only remains found in it are the roots of gigantic trees (see *Lign.* 36); for such the stigmariæ are now proved to have been, and not aquatic plants, as was formerly supposed (*Bd.* p. 476).

Secondly, a bituminous mass (*Coal*), composed of coniferous wood, gigantic ferns, club-mosses, &c.; occasionally with trunks of trees penetrating vertically through it.

Thirdly, a deposit of drift or water-worn materials (*the Roof*), mixed with the foliage and stems of numerous species of terrestrial plants; the whole appearing to have been subjected to the action of currents. The first, or *Under-clay*, may have been the natural soil, in which the stigmariæ grew; the next,—the *Coal*,—the carbonized stems, and other remains of the trees to which the roots belonged: and the last, or uppermost, forming the roof of the coal, may

have resulted from the foliage and branches of a prostrate forest, overwhelmed and buried beneath the transported detritus of distant rocks.

These phenomena may be explained by supposing the inundation of a thickly-wooded plain from an irruption of the sea; or of a vast inland lake, occasioned by the sudden removal of some barrier; or by a subsidence of the tract of country on which the forest grew. But when we find an accumulation of strata, in which triple deposits of this kind are repeated some thirty or forty times through a thickness of many thousand feet, this solution of the problem is not satisfactory. Not only subsidence after subsidence must have taken place, but the first submergence have been followed by an elevation of the land—another soil, fit for the growth of forest trees, must have been produced—another generation of vegetables, of precisely the same species and genera, have sprung up, and arrived at maturity—and then another subsidence, and another accumulation of drift. And these periodical oscillations in the relative level of the land and water must have gone on uninterruptedly through a long period of time, not in one district or country only, but in various parts of the world, during the same geological epoch. At present I do not think we have data sufficient to explain these phenomena; what has been advanced may, perhaps, serve to elicit further information, by pointing out the difficulties in which the question is involved, and showing what interesting fields of discovery are still unexplored, and how comprehensive and important are the objects that come within the scope of geological investigation.*

I will conclude this chapter with the following beautiful reflections of Dr. Buckland on the origin and nature of Coal,

* I would refer the student for a fuller consideration of the phenomena thus briefly noticed, to the 6th edition of my Wonders of Geology, pp. 669, 718, 731.

and the changes it undergoes when rendered subservient to the necessities and luxuries of man.

"Few persons are aware of the remote and wonderful events in the economy of our planet, and of the complicated applications of human industry and science, which are involved in the production of the coal that supplies with fuel the metropolis of England.

"The most early stage to which we can carry back its origin, was among the swamps and forests of the primeval earth, where it flourished in the form of gigantic *Calamites*, and stately *Lepidodendra*, and *Sigillariæ*. From their native bed, these plants were transported into some adjacent lake, or estuary, or sea. Here they floated on the waters, until they sank saturated to the bottom, and being buried in the detritus of adjacent lands, became transferred to a new estate among the members of the mineral kingdom. A long interment followed, during which a course of chemical changes, and new combinations of their vegetable elements, converted them to the mineral condition of coal. By the elevating force of subterranean agency, these beds of coal have been uplifted from beneath the waters, to a new position in the hills and mountains, where they are accessible to the industry of man. From this fourth stage, coal has been removed by the labours of the miner, assisted by the arts and sciences, that have co-operated to produce the steam-engine, and the safety-lamp. Returned once more to the light of day, and a second time committed to the waters, it has, by the aid of navigation, been conveyed to the scene of its next and most considerable change by fire; a change during which it becomes subservient to the most important wants and conveniences of man. In this seventh stage of its long eventful history, it seems, to the vulgar eye, to undergo annihilation; its elements are, indeed, released from the mineral combinations which they have maintained for ages, but their apparent destruction is only the com-

mencement of new successions of change and of activity. Set free from their long imprisonment, they return to their native atmosphere, from which they were absorbed by the primeval vegetation of the earth. To-morrow they may contribute to the substance of timber, in the trees of our existing forests; and having for a while resumed their place in the living vegetable kingdom, may, ere long, be applied a second time to the use and benefit of man. And when decay or fire shall once more consign them to the earth, or to the atmosphere, the same elements will enter on some further department of their perpetual ministration in the economy of the material world." *

Bd. p. 481.

CHAPTER VI.

FOSSIL VEGETABLES.

In the present section of this work, I propose to explain the botanical arrangement and nomenclature of fossil plants; and figure and describe one or more species of the genera that are most likely to come under the observation of the student, either in public or private collections, or in the course of his researches in the field.

To determine the botanical relations of fossil leaves and stems, reference must be had to works expressly devoted to the subject; namely, the "*British Fossil Flora*," by Dr. Lindley and Mr. Hutton, and the "*Histoire des Végétaux Fossiles*," by M. Adolphe Brongniart. The classification of the last-named eminent botanist is here adopted, as the most easy of application.

With regard to the nomenclature, it may be necessary to remark, that when a fossil plant undoubtedly belongs to a recent genus, the usual botanical name is employed: for example, *Equisetum Lyellii*; when the fossil does not possess all the generic characters, yet is evidently allied to a recent genus, the term *ites* (from λίθος, *lithos*, stone), is added—as *Equisetites*, *Palmacites*, &c.; and this termination is invariably adopted by some authors. When the fossil plant differs altogether from any known type, it is distinguished by some arbitrary generic name, as *Bucklandia*, *Sigillaria*, &c.

There are also a few provisional genera for the reception

of fossil leaves, fruits, and stems, whose characters and relations are but imperfectly known; as *Carpolithes*, *Endogenites*, &c. Upon these principles the present arrangement has been founded: the progress of discovery will, of course, be continually adding to the list, and the classification require to be modified.

The following account of the principal types of the ancient floras whose relics are preserved in the mineral kingdom, though commencing with those of the most simple structure, the *Cryptogamia*, and advancing to the higher orders, is not strictly botanical; for it was found convenient, in some instances, to notice certain species and genera of different orders under the same head, from their occurrence in the same geological formations.

It is estimated that not more than two thousand species of plants have been discovered in a fossil state, while the known recent species amount to upwards of eighty thousand.

Cellular Cryptogamia; Algæ.—The plants designated by botanists *Algæ*, and commonly known as sea-weeds, lavers, and fresh-water mosses, are of the most simple structure—mere aggregations of cells—but present innumerable varieties of form and magnitude: many species are mere vesicles of such minuteness as to be invisible to the unassisted eye, except accumulated in countless myriads, when they appear as a green, purple, or reddish, slime in the water; or as a film on wood or stone, or on the ground, in damp situations; while others are tough branched marine plants, many fathoms in length.

The Algæ form three principal groups: 1. the *jointless*, as the Fuci, the Dulses, Tangles, and Lavers: 2. the *jointed*, which are composed of thread-like articulated tubes; such are the fresh-water Confervæ: 3. the *disjointed*, or Brittleworts, so called from their spontaneous self-division, which is in some kinds complete, in others only partial; and these,

by separating transversely, and leaving each cell or *frustule* attached at the angles, produce those beautiful chains of angular green transparent cases, so constantly seen under the microscope when substances from fresh-water streams or lakes are submitted to examination.

As many of these forms are endowed with spontaneous motion, and possess other properties common to animal organization, it is not surprising that their vegetable nature was doubted, and that even so profound a naturalist as M. Ehrenberg placed them in the animal kingdom: the greater number being comprised in his family of *Bacillariæ*, were described in the former edition of this work, as Infusoria or Animalcules; in conformity with the classification of the illustrious microscopist, whose splendid works and indefatigable labours have so greatly promoted the advancement of microscopical investigation.*

These minute vegetable organisms are placed by botanists in two tribes, the *Diatomaceæ* or the *Brittle-worts*, and the *Desmidieæ*. The latter are exclusively inhabitants of fresh-water, while a large proportion of the former are marine plants. Some naturalists (M. Brébisson) restrict the name *Diatomaceæ* to those species which secrete siliceous envelopes; and that of *Desmidieæ* to those whose structures are not siliceous, and are reducible by heat to carbon. As the durable parts of these plants alone concern the geologist, the name *Diatomaceæ* will be employed as a general term in reference to their fossil remains.

These tribes of Algæ abound in every lake and stream of fresh-water, in every pool or bay, and throughout the ocean from the equator to the poles. Certain kinds of sea-weeds secrete carbonate of lime; but the Diatomaceæ have the power of separating silex, or the earth of flint, from the

* The whole of the objects called *Infusoria* in the first edition of "The Medals of Creation" belong to various kinds of Diatomaceæ.

water, by some unknown process, and their tissues are composed of pure quartz; hence, under the microscope, their remains, consisting wholly of rock crystal, exhibit the most exquisite forms, elaborately fretted and ornamented (see *Lign.* 4). After the death and decomposition of these plants, their durable frustules or cases appear as colourless discs, cups, spheres, shields, &c., and these accumulate at the bottom of the water in such inconceivable numbers, as to form strata of great thickness and extent. Slowly, imperceptibly, and incessantly, are the vital energies of these atoms separating from the element in which they live the most refractory and enduring of mineral substances, silex, and elaborating it into imperishable structures, and thus adding enormous contributions to the accumulations of detritus, which make up the sedimentary rocks of the crust of the globe.

The extent of this infinitesimal flora throughout regions where no other forms of vegetation are known, is strikingly demonstrated by the observations of our eminent botanical traveller, Dr. Joseph Hooker, in his account of the Antarctic regions.*

"Everywhere," Dr. Hooker states, "the waters and the ice alike abound in these microscopic vegetables. Though too small to be visible to the unassisted eye, their aggregated masses stained the iceberg and pack-ice wherever the latter were washed by the sea, and imparted a pale ochreous colour to the ice. From the south of the belt of ice which encircles the globe, to the highest latitudes reached by man, this vegetation is everywhere conspicuous, from the contrast between its colour and that of the white snow and ice in which it is imbedded.

"In the 80° of south latitude all the surface ice carried along by currents, and the sides of every berg, and the

* "On the Botany of the South Polar Regions;" in Sir J. Ross's Voyage of Discovery.

base of the great Victoria barrier itself—a perpendicular wall of ice, from one to two hundred feet above the sea level—were tinged brown from this cause, as if the waters were charged with oxide of iron. The majority of these plants consist of simple vegetable cells enclosed in indestructible silex; and it is obvious that the death of such multitudes must form sedimentary deposits of immense extent.

"The universal existence of such an invisible vegetation as that of the Antarctic Ocean is a truly wonderful fact, and the more so from its being unaccompanied by plants of a high order. This ocean swarms with mollusca, and entomostracous crustaceans, small whales, and porpoises; and the sea with penguins and seals, and the air with birds; the animal kingdom is everywhere present, the larger creatures preying on the smaller, and these again on those more minute; all living nature seems to be carnivorous. This microscopic vegetation is the sole nutrition of the herbivorous animals; and it may likewise serve to purify the atmosphere, and thus execute in the Antarctic latitudes the office of the trees and grasses of the temperate regions, and the broad foliage of the palms of the tropics."

Dr. Hooker also remarks that the siliceous envelopes of the same kinds of diatomaceæ now living in the waters of the South Polar Ocean, have contributed in past ages to the formation of European strata; for the tripoli and the phonolite stones of the Rhine, contain the siliceous envelopes of identical species.

Such are the comments of one of our most distinguished botanists, on the phenomena under review. The reader will perhaps ask, what then are the essential characters which separate the animal from the vegetable kingdom? To this question it is impossible to give a satisfactory reply: perhaps the only distinction that will be generally admitted by zoologists and botanists is the following:—*animals require*

organic substances for their support; vegetables derive their sustenance from inorganic matter.

RECENT DIATOMACEÆ. *Plate IV.*—To familiarize the reader with the nature of these vegetable organisms, a few recent species are represented in *Plate IV.*, coloured as they appear when alive, under the microscope; the figures are magnified as expressed by the fractions.

Xanthidium. Plate IV. figs. 1, 2, 3, 4, 5.—The case or frustule of this genus consists of a hollow, siliceous globe, beset with spines. The increase of the *Xanthidia* by self-division, produces the double appearance in the figures, all of which are in the progress of separation.*

Pyxidiculum. Plate IV. fig. 2.—The case is a little saucer-shaped box, and is invested by a membrane.

Bacillaria. Plate IV. fig. 6.—A simple siliceous frustule, of a prismatic shape, forming a brilliant chain, which often appears in zigzag, in consequence of incomplete self-division. An immense number and variety of forms are placed in this family by Ehrenberg, with a multitude of generic and specific names. The fresh-water species inhabit every pond and lake, and the marine every sea. Fossil species are equally abundant.

Cocconeis. Plate IV. fig. 7.—This is a very elegant type; the frustule consists of a simple siliceous case, with a central opening; it never occurs in chains like the former. It has been found fossil near Cassel.

Navicula. Plate IV. figs. 8, 9, 14, 15.—The plants of this genus are free, and float in the water apparently by the agency of cilia. Their case is a boat-like envelope with six

* The organisms so abundant in the flint and chalk, and which were referred by M. Ehrenberg to this genus, and consequently described under the name of Xanthidia by myself and others, are certainly in nowise related to the recent forms: they are flexible envelopes, and probably belong to zoophytes; as will be shown in the sequel.

openings, composed of pure silex, and in many species is exquisitely ornamented. Figs. 8 and 9. show a living *Navicula*, viewed in front, and in profile: in *fig.* 9 are represented the currents produced when the body is moving through the water; after Ehrenberg. Fossil *Naviculæ* abound in many tertiary strata.

Galionella. *Plate IV. figs.* 10, 11.—These algæ are free, and the frustules of a cylindrical, globular, or discoidal form; they occur in chains, in consequence of the self-division being imperfect, and the new individuals remaining attached to the old. The *Galionellæ* are most abundant and prolific, and inhabit every pool, stream, and lake: fossil species occur in the Virginian marls, and other strata.

Synhedra. *Plate IV. fig.* 12.—The frustules are siliceous, and of a slender, elongated form. The plant is attached by the base (*fig.* 12 *a.*) in youth, and afterwards becomes free. It is found fossil in the Mountain-meal of Santa Fiora, and many other deposits.

Podosphenia. *Plate IV. fig.* 13.—The frustule is cruciform, or wedge-shaped, and attached in youth by the small end, but afterwards becomes free. These plants are often arranged in clusters, as in the figure. M. Ehrenberg states that they inhabit the sea, and not fresh-water; but I have found them in streams communicating with the Thames. *Podospheniæ* abound in the polishing slate of Bilin.

Eunotia. *Plate IV. figs.* 16, 17.—The frustule is siliceous, and either simple or bivalve; flat below, and convex, and often richly dentated above. An empty case is shown *fig.* 16; and a group of living *Eunotiæ* attached to a stem of conferva, *fig.* 17. Several fossil species have been discovered at Santa Fiora.

That the general reader, whose attention is for the first time directed to this subject, may be prepared for the enor-

mous deposits of fossil diatomaceæ that are found in some formations, I subjoin the observations of Dr. Bailey on an elegant fragile species, which hangs together in clusters, appearing like spiral chains, and is about $\frac{1}{20}$ of a line in diameter; it is named *Meridion vernale.*

"This fresh-water plant is seen in immense quantities in the mountain brooks around West Point, the bottoms of which are literally covered in the first warm days of spring with a ferruginous-coloured mucous matter, about a quarter of an inch thick, that, on examination by the microscope, proves to be filled with millions and millions of these exquisitely beautiful siliceous organisms. Every submerged stone, twig, and spear of grass, is enveloped by them; and the waving plume-like appearance of a filamentous body covered in this manner, is often extremely elegant. Alcohol completely dissolves the endochrome (*soft colouring matter*) of this species, and the frustules are left as colourless as glass, and resist the action of fire."*

The yellow or ochreous scum observable in ponds, ditches, and stagnant pools, is an aggregation of diatomaceæ, whose frustules are ferruginous, and of such extreme minuteness, that a billion of their cases would not be more than a cubic inch in bulk.†

FOSSIL DIATOMACEÆ.—From this notice of a few recent types, we proceed to the investigation of the fossil remains of this tribe of Algæ.

In peat-bogs and swamps, both of modern and ancient date, masses of a white marly or siliceous paste (*hydrate of silica*), are often observed, and these are found upon microscopical observation to be wholly made up of the frustules of *Naviculæ*, *Bacillariæ*, *Galionellæ*, &c., with an intermixture of the needle-like spicules of fresh-water sponges. Many of the peat-bogs of Ireland contain layers of a white

* Trans. Amer. Assoc. Geolog. 1843, p. 152. † Ehrenberg.

earthy substance, which, when dry, is of the appearance and consistence of friable chalk, and entirely consists of the siliceous cases of various kinds of diatomaceæ.

LIGN. 4. SILICEOUS FRUSTULES OF DIATOMACEÆ, AND SPICULES OF SPONGILLÆ; from a deposit on the banks of the river Bann, Ireland.

(Seen by transmitted light, and highly magnified.)

FOSSIL DIATOMACEÆ FROM IRELAND, *Lign.* 4.—Dr. Drummond describes a bed of this kind near the base of the Mourne Mountains, in the County of Down, Ireland. It consists of a very light white substance, resembling in appearance carbonate of magnesia: it has a coarse and somewhat fibrous fracture, and is easily reduced to powder. It is almost entirely siliceous, and is composed of the cases of diatomaceæ of the usual fresh-water species, without any admixture of inorganic matter.*

On the banks of the river Bann, in the same county, there is an extensive stratum of a similar earth, and which, from being in much request for polishing plate, is locally known as Lord Roden's plate powder. This earth is wholly made up of the siliceous frustules of many kinds of this tribe

* Mag. Nat. Hist. New Series, vol. iii. p. 353, July 1839.

of Algæ, and a few grains under the microscope yield a great variety of exquisite forms: figures of several are given in *Lign.* 4, from specimens of this earth, with which I was favoured by the Countess of Caledon. They comprise two or three species of Navicula, Galionella, Coscinodiscus, Gomphonema, Bacillaria, Stauroneis, &c., and spicules or spines of fresh-water sponges.*

Beds of siliceous marl—that is, of argillaceous earth combined with a large amount of minute particles of silex, all of which prove to be organisms when examined by a high magnifying power,—have been found in numerous places not only in England, but all over the world, since M. Ehrenberg first directed attention to their nature and origin.

Near Bryansford (Newcastle), Binstwick in Holderness, and in the Fens of Lincolnshire and Cambridgeshire, extensive fresh-water microphytal deposits have been discovered and examined.

From our Antipodes I have received many examples of these vegetable earths. My eldest son, Mr. Walter Mantell, discovered an extensive bed of white marl on the banks of the great brackish-water lake of Waihora, in the middle island of New Zealand, consisting entirely of frustules of Bacillariæ. From New Plymouth he obtained some new and exquisite forms of Navicula, Stauroneis, &c.; ranges of low hillocks of sand, of considerable extent, being made up of microphytes (*microscopic plants*).†

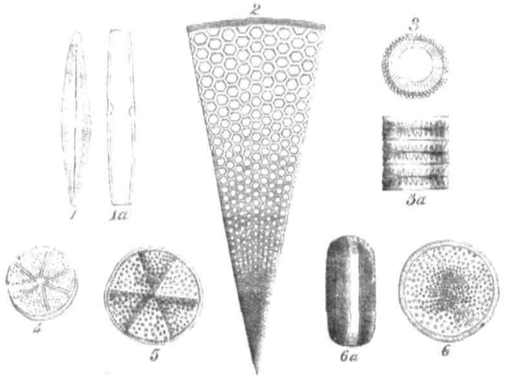
Mr. Dean, of Clapham Common, informs me that a

* The names of the usual kinds of Diatomaceous frustules may be learnt by reference to Mr. Andrew Pritchard's abstract (with coloured figures) of Ehrenberg's Infusoria. The splendid work of Mr. Ralfs, on the British Desmidieæ, 1 vol. 4to, with coloured plates, is the best guide for those who wish to study the recent plants.

† See a Memoir on the Geology and Fossil Remains of New Zealand, from the researches of Walter Mantell, Esq.—*Geol. Journal*, vol. vi. *pl.* 29.

spokes of a wheel, hence named *Actinocyclus* (*Lign.* 7, *figs.* 4, 5), and spicules of Sponges, are also abundant.

When a few grains of the marl are prepared, and mounted on a glass, almost all these varieties will be manifest, so



LIGN. 7. MICROPHYTES* FROM THE RICHMOND-EARTH; *highly magnified. Tertiary. Virginia.*

Fig. 1.—NAVICULA. 1*a*. Side view.
2.—COSCINODISCUS RADIATUS; a portion of the circular shield.
3.—GALIONELLA SULCATA; the upper figure shows the transverse face of one of the frustules.
3*a*. Three united cells viewed laterally.
4, 5.—ACTINOCYCLUS. Two species.
6.—COSCINODISCUS PATINA; transverse view.
6*a*. Lateral view.

largely is this earth composed of organic structures; in fact, very few inorganic particles are intermixed, the merest

* As the term *Infusorial-earth* must be abandoned, it will be convenient to substitute a name simply expressive of the nature of the most abundant organisms that enter into the composition of these deposits: that of *Microphyta*, or *Microphytes*, (from μικρὸς, *mikros*, small, and φυτὸν, *phyton*, a plant), signifying very minute vegetables, may perhaps be admissible: in this sense the word *microphytal* is employed in these pages.

pellicle left by the evaporation of a drop of water in which some of the marl has been mixed, teeming with the most beautiful structures.

At Petersburg, in Virginia, a sandy marl occurs, interstratified with deposits which, from their shells, are referred to the older tertiary formations. Probably this marl is a continuation of that of Richmond, but it is full of many new forms, associated with those common in the earth of the latter locality.*

It is an interesting fact, (first observed by Mr. Hamlin Lee,) that the common Scallop (*Pecten maximus*), as well as the Barnacle (*Balanus*), feed on diatomaceæ, and their stomachs generally contain numerous cases of Coscinodisci, Dichtyochi, Actinocycli, &c. : a slide prepared and mounted with the contents of the stomachs of these mollusks, presents an assemblage of forms identical with those found in the tertiary earths of Virginia.†

In the mud of the quicksands on the shore at Brighton, Mr. Reginald Mantell found recent Coscinodisci, &c. associated with fossil polythalamia that had been washed out of the chalk, and precipitated with the frustules of the recent diatomaceæ, into the sediments now in progress.

The prevalence of marine and fresh-water forms in the same deposit is not unusual; and the remarks of Dr. Bailey on this fact are so pertinent, that I insert them, as a salutary caution against hasty generalizations on subjects connected with these investigations. After describing a species of Galionella (*G. moniliformis*), as an inhabitant only of salt and brackish water, and stating that he had also

* Dr. Bailey, with great liberality, has so amply supplied myself and other observers with specimens of these deposits for examination, that the fossils above described are familiar to all British microscopists. Figures of many of those organisms are given in the American Journal of Science.

† See my "Thoughts on Animalcules," p. 103.

found it sixty miles up the Hudson River, near West Point, Dr. Bailey observes—"The Fauna and Flora of the Hudson at this place would, if in a fossil state, be rather puzzling to the geologist, on account of the singular mixture of marine and fluviatile species. While *Valisneria* and *Potamogeton* (two common fresh-water plants), grow in such vast quantities, in some places, as to prevent the passage of a boat, and the shore is strewn with fluviatile shells (such as Planorbis, Physa, &c.) in a living state, yet the above plants are entangled with Algæ (sea-weeds), and marine parasitic zoophytes; while the rocks below low-water mark are covered with Balani (*barnacles*) and minute corallines, and the marine Flora is represented by vast quantities of very elegant sea plants."*

I must here close this extended notice of the fossil remains of a class of vegetable organisms, which, though for the most part invisible to the unassisted eye as individual forms, constitute by their inconceivable multitudes an important element in the formation of sedimentary deposits. The fact of their having been formerly treated of as animalcules, and generally regarded as belonging to the animal kingdom, rendered a full consideration of the phenomena necessary, in order to place the subject before the reader in a clear and comprehensive point of view.†

CONFERVITES.—The cellular aquatic plants named Confervæ are sometimes found in transparent quartz pebbles, and in chalk, appearing as delicate simple or branched filaments, which, by the aid of the microscope, are seen to be

* American Journal of Science, vol. x. p. 41.

† As both the recent and fossil frustules of Diatomaceæ are beautiful objects for the microscope and polariscope, they are in much request. Specimens mounted on glass slides may be had of Mr. Topping, and Mr. Poulton. See Appendix.

articulated. Seven species are described by authors, but the vegetable nature of some of these is doubtful. A beautiful species in Chalk, first noticed by the late Samuel Woodward, Esq. (author of the Geology of Norfolk), is here figured.

LIGN. 8. CONFERVITES WOODWARDII; *nat.*
Chalk, Norfolk.

FOSSIL FUCOIDS.—Of the tribe of Algæ which comprises the sea-weeds that are not articulated, many fossil species occur in very ancient, as well as in modern, fossiliferous deposits. In the Lower Silurian rocks of North America, beds of limestone of great extent are full of a large digitated Fucus (*Fucoides Alleghaniensis*).* The Firestone or Malm-rock of Bignor in Sussex abounds in a ramose variety (*Fucoides Targionii, Veg. Foss.* p. 56), of which specimens are figured in the vignette of this volume, and in *Lign.* 9.

CHONDRITES.—These fossil algæ approach nearest to the living species of *Chondrus* (hence the name of the genus). The frond is thick, branched, dichotomous, with cylin-

* Figured and described in Dr. Harlan's Medical and Physical Researches: Philadelphia, 1835, p. 393.

drical or claviform divisions, with a smooth surface and without tubercles. The substance of the Bignor fossils is a white friable earth, which strikingly contrasts with the dark grey malm-rock that forms the matrix. As the Sussex Chalk Chondrites appear to be distinct from the Tertiary species named by M. Brongniart *C. Targionii*, I have, at the suggestion of Mr. Morris, substituted *C. Bignoriensis*, to indicate the locality in Sussex in which I discovered it forty years since.

LIGN. 9.
CHONDRITES BIGNORIENSIS; *nat.*
Malm-rock. Bignor, Sussex.

In the chalk flints ramose fuci occasionally occur, but not in a state of preservation that admits of the determination of the forms of the originals

The tertiary marls and limestones of Monte Bolca yield several beautiful species of Algæ, one of which is figured in *Lign.* 10. It is referred to the fossil genus *Delesserites* (Sternberg), which includes those algæ that have thin, and flat or undulated, smooth, membranous fronds, with a median rib.

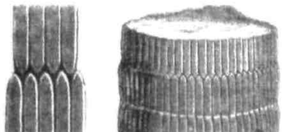
Of the little plants comprised in the class of cellular cryptogamia, which have stems, leaves, and fructification, but no true vessels, two or three species of Moss and Liverwort have been met with in tertiary strata. Mosses as well as Fuci are occasionally imbedded in quartz pebbles, in which they appear of their natural colour, and apparently floating in the transparent medium. A beautiful green moss, with a Conferva twined round its base, is figured *Lign.* 11, p. 104, from a specimen described by the late Dr. Macculloch. It is supposed to be related to *Hypnum* (*Geol. Trans.* vol. ii.).

Moss-agates and Mocha-stones.—The beautiful siliceous pebbles called *Moss-agates*, and *Mocha-stones*, will so often come under the notice of the collector, that, although but extremely few, if any, of these objects contain organic remains, the arborescent substances they inclose being merely metallic oxides, a few remarks on their nature may be expected. The late Dr. Macculloch paid considerable attention to the investigation of these bodies, and believed that some of the objects imbedded in the pure and compact quartz were really of vegetable or animal origin; the specimen figured *Lign.* 11 is of this kind; the fossils being apparently cellular cryptogamous plants. In *Geol. Trans.* vol. ii., other examples are figured and described by the same sagacious observer. Mr. Bowerbank is of opinion that spongeous structure enters into the composition of almost all the moss-agates, and I have no doubt that in some instances such organisms are present: but in by far the greater number of agates and mocha-stones the inclosed bodies are mere crystallizations; they are arborescent or dendritical oxides of manganese, copper, chlorite, iron, &c.

Lign. 10. Delesserites (Fucoides) Lamourouxii.
Tertiary. Monte Bolca. (Veg. Foss. Br.)

M. Brongniart, who carefully examined a great number of agates and pebbles, with the view of determining if vege-

fine specimens have been collected, especially from the vicinity of Whitby. In the sandstone of the Inferior Oolite of the Cleveland Hills, Yorkshire, numerous stems of this colossal marestail have been observed standing erect, as if occupying the position in which they grew; the same fact was also discovered at Carlton Bank, near Stokesly, forty miles from the coast. In both localities fossil shells of fresh-water mussels (*Uniones*) were associated with the vegetable remains.



LIGN. 13. EQUISETITES COLUMNARIS. (Ad. Brongn. Pl. 13.) *Lower Oolite. Whitby.*

Fig. 1.—Portion of a stem, showing two articulations, and an intermediate constriction. ⅓ *nat.*

2.—*A few of the denticulations* produced by the sheath. *nat.*

This plant is a true equisetum, differing chiefly from existing species in its gigantic size and arborescent character. The sheaths surrounding the stem, and the verticillate linear leaves, are preserved in some examples: and in all, the furrows left by the imprints of the sheaths are more or less strongly impressed. The stem is not channelled throughout, as in *Calamites*, the carboniferous plant whose stems at first sight might be mistaken for those of Equisetites, but which are entirely distinct, as will be explained hereafter. The Equisetites columnaris is peculiar to the Oolite; it does not occur in the coal-measures. Specimens have been discovered which indicate a height of twenty feet, and a diameter of several inches.*

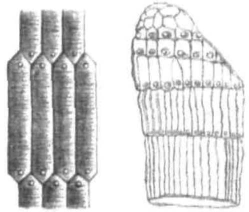
A small species of Equisetum (*Eq. Brodiei*†) occurs in the insectiferous limestone of the lower Lias, at Strensham, Worcestershire, associated with the foliage of fresh-water endogenous plants resembling the *Potamogeton*, or pondweed, and of supposed dicotyledonous vegetables.

* See Hist. Vég. Fossiles, p. 115.

† Prof. Buckman, in Geol. Journal, vol. vi. p. 413.

CALAMITES. *Lign.* 14, 15.—Stem articulated, regularly furrowed longitudinally, the articulations naked, or studded with tubercles.

The plants of this genus were supposed to be related to the marestail, but to differ in the absence of the encircling sheaths, and in being uniformly striated; but an examination of specimens in a better state of preservation than those previously known, shows their affinity to the gymnosperms. Some of the species are of a gigantic size, being from one to three feet in diameter, and from thirty to forty feet in height. Calamites abound in the coal formation, and must have constituted an important feature in the forests of the carboniferous period; they occur also in more ancient deposits, and some species belong to the earliest terrestrial Flora of which any vestiges are known. In most instances when specimens are found lying in the same plane with the strata, they are pressed flat, but those occurring in a vertical position retain their natural cylindrical form. An outer crust or cylinder of coal generally invests the stem, but traces of the internal structure are rarely preserved.

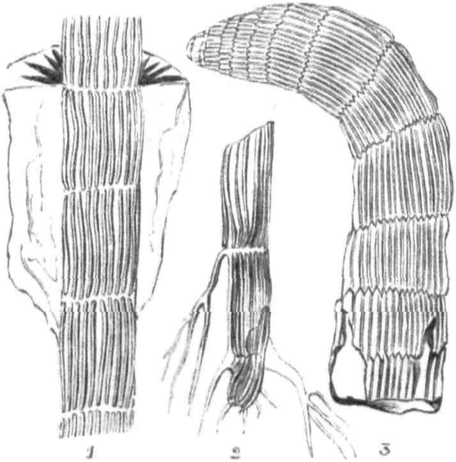


LIGN. 14. CALAMITES DECORATUS. $\frac{1}{3}$ *nat.*
(Ad. Brongniart. Pl. 14.)
Coal Formation. Yorkshire.
Fig. 1.—Part of a stem, showing the tubercles for the attachment of leaves.
2.—A portion of the same on a larger scale.

The Calamite consists of a large central column of tissue, surrounded by a ligneous cylinder. The central part has in most instances perished after the death of the plant, and the cavity thus left been filled up with mineral matter. As the hollow ligneous zone is almost always carbonized, and very friable, it is seldom attached

to the cast, and consequently the surface of the latter is generally jointed and ribbed.

The true external surface of the cortical investment is marked with longitudinal striæ, without any indications of joints or constrictions; but the position of the original articulations is indicated in some specimens by the *presence of small verticillate scars, to which leaves were appended,** as in the example figured by M. Brongniart, of which *Lign.* 14, fig. 1, is a reduced figure.



LIGN. 15. CALAMITES, IN COAL SHALE.

Fig. 1.—CALAMITES RADIATUS, with the remains of one of the sheaths.—½ *nat.*
2.—Stem, with remains of roots.—½ *nat.*
3.—CALAMITES APPROXIMATUS, showing the curved *lower* end of the plant.†—½ *nat.*

The stellate appearance on the upper part of the stem figured in *Lign.* 15, *fig.* 1, is produced by the zone of leaves

* See Mr. Dawes, "*On the Structure of Calamites,*" Proc. Geol. Soc. 1851, vol. vii. p. 197.

† This specimen has been inadvertently drawn with the base uppermost.

which surrounded the joint: this character is entirely distinct from the sheath of the Equisetum shown in *Lign.* 12. This specimen points out the importance of carefully examining and preserving the stone around fossil stems; had this precaution been lost sight of in this instance, no knowledge would have been obtained of this important botanical character. It is rarely that any traces of the roots remain; the fossil figured (*fig.* 2) is from the *Foss. Flor.* A beautiful example of the foliage of a species of Calamites is represented in *Lign.* 59, *fig.* 2.

Upright stems of Calamites occur in the Coal formation near Pictou, in North America; and in one example a group of ten or twelve stems, covering an area of two square feet, sprung from one root.*

Filicites, or Ferns.

We now arrive at the consideration of one of the most interesting families of the vascular cryptogamia that adorned the Flora of the ancient world, and the living species of which impart beauty and elegance to the scenery of the countries where they prevail. The most essential character of these vegetables, is that of developing their fructification on the leaves; a fact familiar to every one who has even but cursorily examined the Polypody growing on our walls, or the Brake of our hedge-rows and commons. The largest species of British ferns scarcely exceed four or five feet in height; but the arborescent or tree-ferns, of warm climates, attain an altitude of from thirty to forty feet. There is too this peculiarity in the arborescent forms, that while in our indigenous species the leaves surround the stem, and incline towards the upper part of the plant, the foliage of the former bends downwards

* Dawson, Geol. Proc. vol. vii. p. 195. See Sir C. Lyell's Travels in North America, vol. ii. p. 195.

and spreads out from the crown, or summit, into an elegant *canopy*.

The leaves of our branched ferns are persistent, and when shed, the markings left by their attachment to the stalk are soon obliterated. In the arborescent ferns, on the contrary, the petioles become detached from their bases, and fall entire, leaving scars or cicatrices on the stem; and these impressions are so regularly and symmetrically disposed, as to afford characters by which the trunks may be distinguished from those of other trees. The stems of the tree-ferns are therefore easily recognized in a fossil state

LIGN. 16. PECOPTERIS SILLIMANI; *nat.*

Coal Shale. Ohio.

a. The Stem.
b. Leaf-stalk, or petiole.
c. Leaf, or frond, which is bipinnate.
d. e. Leaflets, or pinnæ; the upper, *d*, are entire; the lower, *e*, are pinnatifid.
f. The pinnules, lobes, or segments.
g. The midrib, or median vein.
h. The veins. The veins are introduced in the leaflets, *d*; but in the lower ones, *e*, the midribs only are marked.

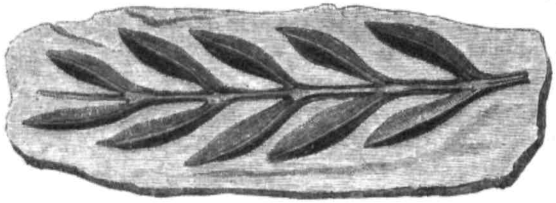
externally, by their cylindrical forms without ramification, and by the regular disposition and peculiar character of the

scars left by the separation of the petioles; and internally by that peculiar zone, formed of bundles of ligneous tissue inclosed in sheaths, which encircles the central axis, as shown in the transverse sections in *Lign.* 2, *ante*, p. 62. The leaves may be identified by the form of their segments, which are disposed with remarkable regularity, and have a peculiar mode of subdivision; and above all, by the delicacy, evenness, and distribution of the veins. There are upwards of two thousand species of living ferns, and in the fossil kingdom the number is considerable; more than two hundred have been collected from the carboniferous formation. The recent tree-ferns are confined almost exclusively to the equinoctial regions; humidity and heat being the conditions most favourable to their development (*Vég. Foss.* p. 141. *Bd.* p. 461. *Wond.* p. 727).

From the elegance and diversity of form of their foliage, fossil ferns are the most remarkable and attractive vegetable remains in the ancient strata. The greater number are from the coal deposits, the fern-leaves generally occurring in the schists or shales that form the roof of the beds of coal. Many of the strata are made up of carbonized fern-leaves and stems closely pressed together. The roof of a coal mine, when newly exposed, often presents a most interesting appearance, from the abundance and variety of leaves, branches, and stems, that occur either in relief, or impressed on the dark glossy surface. The specimens selected for illustration exhibit the principal modes of venation on which the genera are founded.

The fossil genera have been established by M. Ad. Brongniart, from the form of the leaves and the characters of their venation; that is, the distribution of the vessels. In the following descriptions some botanical phrases are necessarily employed; a few terms of frequent occurrence are explained in *Lign.* 16.

PACHYPTERIS* (*thick-fern*). *Lign.* 17.—In this genus from the lower Oolite, the fronds are pinnated, or bipinnated, the leaflets entire, without visible veins, having but a single



LIGN. 17. PACHYPTERIS LANCEOLATA.
Inferior Oolite. Whitby.

midrib, and contracted at the base. The absence of veins, and the leaflets not being lobed, are the essential generic distinctions.

LIGN. 18. SPHENOPTERIS ELEGANS.
Coal-shale, Waldenburg, Silesia.

SPHENOPTERIS (*wedge-leaf*). *Lign.* 18.—The leaves are twice or thrice pinnated, the leaflets wedge-shaped, contracted or narrowest at their base, and more or less deeply lobed: the lobes divergent and palmated: the veins radiating from the base.

The ferns of this genus are extremely elegant, and comprise upwards of forty species. A beautiful Sphenopteris (*S. affinis, Wond.* p. 716,) occurs abundantly in the fresh-water carboni-

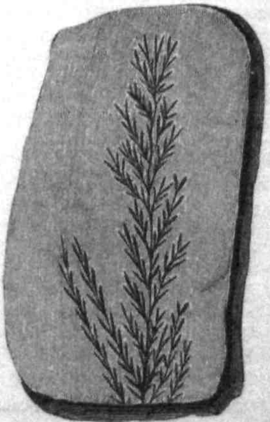
* The names of the genera are derived from *pteris*, fern, to which is prefixed a term indicative of the peculiar characters.

ferous strata at Burdie House, near Edinburgh;* another elegant form, in coal-shale, is represented in *Lign.* 18.

LIGN. 19. SPHENOPTERIS NEPHROCARPA.
Inferior Oolite, Scarborough.
A magnified vein of a leaflet, showing the fructification at the extremities of the lobes, × two diameters.

It is so rarely that the fructification of any species of Sphenopteris is preserved in a fossil state that I am induced to figure a leaflet of a remarkable plant of this genus from the fluvio-marine oolitic deposits of Scarborough. *Lign.* 19 is copied from the lithograph accompanying a notice of some rare plants from that locality, by the eminent botanist, C. J. F. Bunbury, Esq.†

This fossil fern closely resembles certain species of *Dicksonia* (natives of New Granada). Each segment of the leaflet or pinnate is dilated at the apex into a reniform *indusium;* no capsules are visible, the fructification being, probably, in a young state.



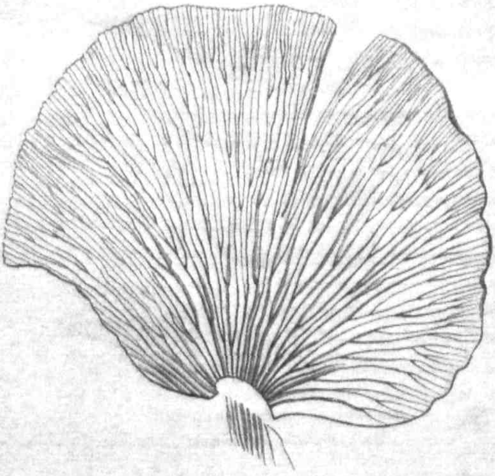
LIGN. 20. SPHENOPTERIS MANTELLI; *nat.*
Wealden, Tilgate Forest.

In the Wealden deposits, both of England and Germany, several species of Sphenopteris abound; one of which (*Foss. Tilg. For.* 1827), often occurs in the calciferous grit of Tilgate Forest, in a beautiful state of preservation: a small branch is figured in *Lign.* 20. This species is characterized

* See Dr. Hibbert's Memoir on the Strata and Fossils of Burdie House. 4to. 1835.

† Geol. Journal, vol. vii. p. 179, pl. xii.

by its slender and minutely divided wedge-shaped leaflets. The Sphenopteris Mantelli did not attain a considerable size; the largest stem I have seen indicated a plant of five or six feet in height. This Sphenopteris is sometimes associated with the remains of a beautiful plant of the genus *Alethopteris*,* the leaflets of which, in some examples, bear the fructification. (*Wond.* p. 394, *Lign.* 89.)



LIGN. 21. CYCLOPTERIS TRICHOMANOIDES; *a single leaflet; nat. Oolite, near Scarborough.*

CYCLOPTERIS (*round-leaf*). *Lign.* 21.—The frond is simple and entire, or but slightly lobed at the margin, and generally orbicular, or kidney-shaped: there is no midrib; the veins are numerous, equal, and dichotomous, or forked, and radiate from the base. The form and disposition of the veins resemble those of some living species of fern; the absence of a median rib, or vein, is the most striking

* p. *Alethopteris elegans* of Dr. Dunker. Mon. Nord-Deutschen Weald.

character of this genus. The fructification is supposed to have been marginal.

NEUROPTERIS (*nerved-leaf*). *Lign.* 22.—The fronds are pinnate or bipinnate; the leaflets more or less ovate or cordiform and entire, adhering to the rachis by their centre only; veins very fine, arched, rising obliquely from the

LIGN. 22. NEUROPTERIS ACUMINATA; *nat.*
In Coal-shale, Yorkshire.

base of the leaflet; the midrib does not extend to the apex of the leaflets, but terminates by subdividing into veins.

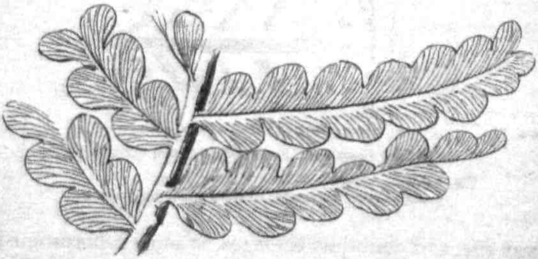
This is a very numerous genus, comprising thirty or more species, which are principally found in the coal-shale. Some of these plants bear a general resemblance to the *Osmunda regalis*, but differ in their essential characters; their leaflets often form the nuclei of ironstone nodules.

GLOSSOPTERIS (*tongue-leaf*). *Lign.* 23.—Leaves simple, sub-lanceolate, gradually contracting towards the base; midrib thick at the base, and vanishing towards the apex of the leaf; veins very fine, curved, oblique, frequently dicho-

LIGN. 23. GLOSSOPTERIS PHILLIPSII; *nat.*
Oolite, Scarborough.

tomous, sometimes reticulated, or anastomosing at their base. The plants of this genus resemble the ferns with simple leaves. A few species only are known; of these, two are from the coal-shale, one from the lias, and one from the oolite.

ODONTOPTERIS (*tooth-leaf*). *Lign.* 24.—Leaf bipinnate, the leaflets adhering to the rachis or stalk by their whole base, which is not contracted; the veins equal, simple, dichotomous, arising side by side from the base of the leaflet; no distinct

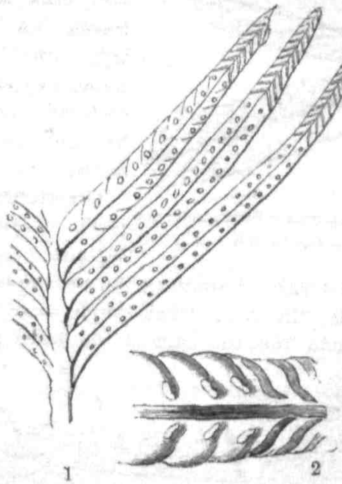


LIGN. 24. ODONTOPTERIS SCHLOTHEIMII; *nat.*
Coal-shale of Saxony.

midrib. In their general aspect these plants resemble some South American species of Osmunda. Five species only are known, all of which belong to the most ancient coal strata.

ANOMOPTERIS (*anomalous fern*—so named because the plants differ from all recent and fossil ferns). *Lign.* 25.—Leaves deeply pinnated; leaflets very long, entire, linear,

traversed by a distinct midrib, equal throughout; secondary veins simple, perpendicular to the median vein, swollen at their free extremities, and not extending to the margin of the leaflet. But one species is known. These leaves are of



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LIGN. 25. ANOMOPTERIS MOUGEOTII; *nat.*

New Red Sandstone; Sulz-les-bains, near Strasburgh.

Fig. 1.—Three leaflets of a very large frond.

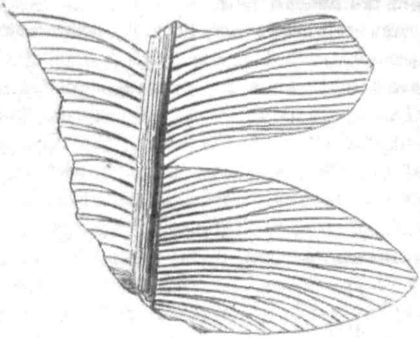
2.—A portion magnified to show the fructification.

great size, and doubtless belonged to some arborescent fern; in several examples the fructification is preserved. My collection contained a splendid specimen from near Strasburgh, presented by the late M. Voltz, which is now in the British Museum.*

TŒNIOPTERIS (*wreathed fern*). *Lign.* 26.—Leaves simple, entire, straight, with parallel margins, traversed by a strong midrib, which extends to the apex; secondary veins, simple

* Petrifactions, p. 32.

or bifurcated at their base, and almost perpendicular to the median vein. These ferns are related to certain species



LIGN. 26. TÆNIOPTERIS LATIFOLIA; *fragment of a frond; nat. Stonesfield Slate.*

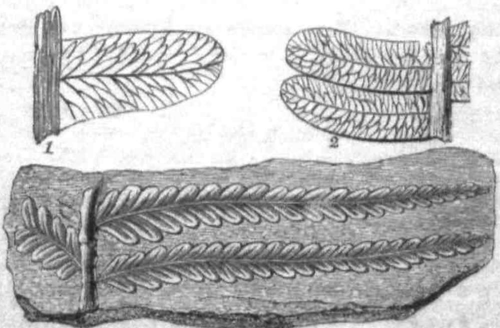
of Polypodium. Three species are known; two from the Oolite, and one from a tertiary deposit. The specimen figured is a fragment.

LIGN. 27. Fig. 1.—PECOPTERIS MURRAYANA; a pinnule with the fructification; *magnified. Inf. Oolite, Scarborough.*
2.—PECOPTERIS LONCHITICA. *Coal-shale, France.*

PECOPTERIS (*embroidered fern*). *Lign.* 27.—Leaves once, twice, or thrice pinnated; leaflets adhering by their whole base to the rachis, rarely by the centre only; traversed by

a strong midrib, which extends to the apex; veins simple, or once or twice dichotomous, proceeding almost at right angles from the median vein.

This genus embraces a very large proportion of the ferns which have contributed to the formation of the coal, and whose leaves and stems are preserved in the associated strata. The originals of many species were undoubtedly arborescent, and attained a large size; some leaves four feet wide, and of a proportionate length, have been observed. More than one hundred species are determined. An American species (*Pecopteris Sillimani*) is figured in illustration of certain botanical terms, *Lign.* 16, *ante*, p. 110. Several species of Pecopteris occur in the fluvio-marine oolitic deposits near Scarborough, and leaves in fructification are not uncommon: *fig.* 1, *Lign.* 27, represents a leaflet slightly magnified

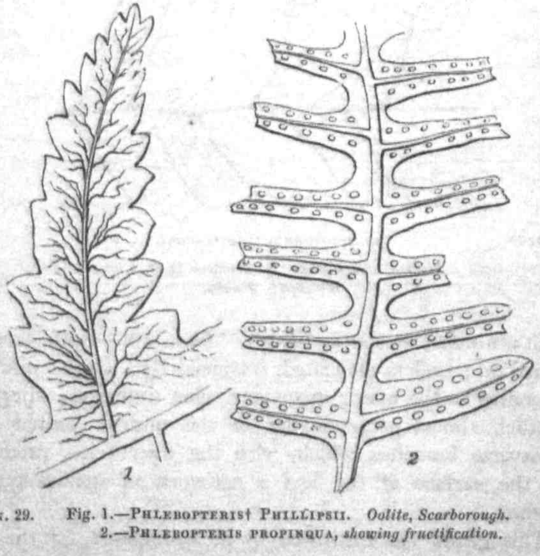


LIGN. 28. LONCHOPTERIS MANTELLI.
Wealden, Tilgate Forest.
Fig. 1 and 2.—Leaflets magnified, to show the reticulated venation.
3.—A fragment of a frond; *nat.*

LONCHOPTERIS (*spear-leafed.*) *Lign.* 28.—Leaves many times pinnated; leaflets more or less adherent to each other at their base, traversed by a midrib; secondary veins reticulated.

The three known species which compose this genus resemble

the living ferns of the genera Lonchitis, Woodwardia, &c. Two have been found in the coal-measures, and one species in the Wealden formation of England and Germany (*Foss. Til. For.* pl. iii.) This last appears to have been a delicate plant; for though fragments are very common in the micaceous grits and clays, any considerable portion of a leaf is of rare occurrence. M. Graves found the same fern near Beauvais in France, in strata, which, from the presence of the fresh-water limestone called Sussex marble, are supposed to be referable to the Wealden epoch. This Lonchopteris is widely spread through the Wealden; and occurs also in the Greensand. Mr. Morris first observed it in the iron-sandstone of Shanklin Chine.*



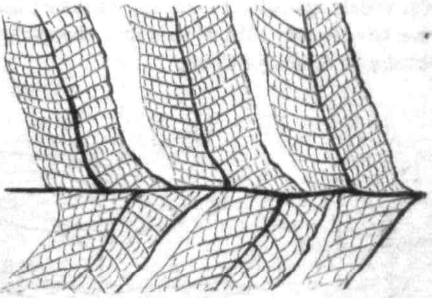
LIGN. 29. Fig. 1.—PHLEBOPTERIS† PHILLIPSII. *Oolite, Scarborough.*
2.—PHLEBOPTERIS PROPINQUA, *showing fructification.*

PHLEBOPTERIS (*veined-leaf*). *Lign.* 29.—Leaves pinnated; leaflets with the margin entire, or crenulated, the

* Geol. I. of W. 2d *Ed.* p. 230. † Comptopteris of M. Ad. Brongniart.

mid-rib strong; secondary veins anastomosing by arches, with large angular spaces, often unequally disposed; the finer veins are simple or divided; the apex sometimes free. The fructification is punctiform, and placed at the apices of the veins.

The foliage of these remarkable ferns has been mistaken for the leaves of dicotyledonous plants; but M. Brongniart has demonstrated that they belong to the present family. Six species have been found in the Oolite and Lias.



LIGN. 30. CLATHROPTERIS MENISCOIDES.

Portion of a leaflet: the original 1½ ft. long.
Wealden? Scania.

CLATHROPTERIS (*latticed-leaf*). *Lign.* 30.—Leaf deeply pinnatifid; leaflets elongated, traversed by a strong midrib extending to the apex; secondary veins numerous, simple, parallel, almost perpendicular to the midrib, united by transverse branches, which, with the finer veins, produce on the surface of the leaf a net-work of quadrangular meshes.

This genus was instituted by M. Brongniart, for the reception of some very large fern-leaves from the shale of Hoer, in Scania, which resemble in structure the foliage of the recent *Polypodium quercifolium*, a native of the East

Indies, and the Moluccas. One leaf was four feet wide, and the leaflets, though imperfect, were eighteen inches long.*

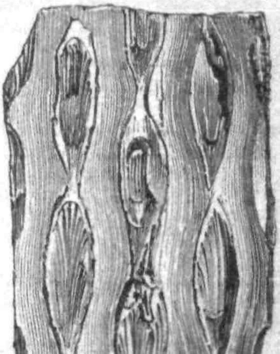
Many other genera of fossil ferns have been established from the form and venation of the leaves, and are described in *Brit. Foss. Flor.*, and other British and foreign works.

STEMS OF ARBORESCENT FERNS. — Notwithstanding the profusion with which the foliage of many kinds of ferns is distributed throughout the coal formation, the undoubted stems of plants of this family are rarely met with; for the numerous tribe called *Sigillariæ* is now removed altogether from this class. It may, however, admit of question whether much of the foliage which, from the analogy of structure, has been referred to ferns, may not have belonged to those trees; for as in the animal kingdom, so in the vegetable, distinct types of living organisms are often found blended in the lost races; and as the stems of recent tree-ferns are even more durable than their leaves, it seems impossible to account for their absence in strata, that inclose entire layers of the foliage matted together. A few fossils, supposed to possess the essential characters of recent fern-stems, have been discovered, and arranged under the following genus.

* Hoer is a little village, situated nearly in the centre of Scania, a province in the southern extremity of Sweden. The Chalk formation appears in several parts of this district, and Carboniferous strata at Hoeganes. To the west of Hoer, there is a range of hills, composed of ferruginous grits, micaceous sandstones, clays, and beds of quartzose conglomerate. It is in these strata that the ferns and other terrestrial plants occur, and no animal remains whatever have been found in them; their geological position appears to be between the Chalk and the Coal, but on this point nothing positive is known. The general analogy of the plants with the group forming the Flora of the Wealden, led M. Brongniart to suppose that the deposits in question belong to that formation; and M. Nillson, of Lund, who examined my collection at Brighton, recognized, among some undescribed plants from Tilgate Forest, forms that he had collected from Hoer. See "*Observations sur les Végétaux Fossiles renfermés dans les Grès de Hoer en Scanie: par M. Ad. Brongniart.*" *Ann. Sc. Nat.* 1825.

CAULOPTERIS (*fern-stem*). *Lign.* 31.—Stems not channelled, marked with discoidal, oblong, or ovate scars, arranged longitudinally; vascular cicatrices numerous.

The fragment of stem here figured, resembles the trunks of some recent tree-ferns in its proportions, and in the number, disposition, and size, of the scars of the leaf-stalks; but these markings differ in their more lanceolate form, and pointed terminations, and in their peculiarly striated surface, from those of any known existing species.



LIGN. 31.
CAULOPTERIS MACRODISCUS. *Coal.*

PSAROLITES (*Silicified Fern-Stems*).—In the New Red sandstone, near Hillersdorf, in the neighbourhood of Chemnitz, in Saxony, silicified stems, apparently of tree-ferns, occur in great numbers. They are remarkably beautiful, and the organization of the original is so well preserved by the silex, that slices, examined by the microscope, display the peculiar structure almost as perfectly as if the plants were recent: transverse sections exhibit the arched bundles of vascular fibres which compose the ligneous cylinder, surrounded by the cellular tissue. From the stellated markings produced by sections of the vessels that compose the tissues, and which are visible to the naked eye, these fossils have obtained the popular name of *Staaren-stein*, or Star-stone. The external surface of the specimens I have examined has a ligneous structure, and is of a dark reddish brown colour; internally the stems are of a dull red, mottled with various

tints of blue and yellow, from the infiltrated chalcedony with which the vessels are permeated.*

An excellent work ("*Dendrolithen*") on these fossils, in which thirty species are described, has been published at Dresden by M. Cotta; who arranges them under the genus *Psaronius* or *Psarolites.* The stem is composed of two distinct parts; an outer zone, consisting of a great number of nearly cylindrical bundles of vessels, supposed to have been roots which proceeded from the stem near its base; and an inner part or axis. In the outer portion, the fossil *air-roots* have a vascular tissue, but there is often a delicate cellular tissue interposed. In the axis the vessels form zig-zag or wavy bands, resembling those of ferns.† These flexuous and vermiform bands are entirely composed of barred or scalariform vessels, similar to those of ferns and club-mosses. The Psarolites are therefore considered by M. Ad. Brongniart to be the bases of the trunks of lycopodiaceous trees, while M. Cotta and other botanists regard them as true arborescent ferns.‡

Dr. Buckland has discovered in the New Red sandstone formation at Allesley, near Coventry, silicified trunks of coniferous trees, and it is not improbable that further research in that locality may bring to light fern-stems like those of Chemnitz.§ Dr. Lloyd, of Warwick, has recently obtained leaves of several coniferæ from the same locality.‖

* See Pict. Atlas (pl. viii.) for coloured figures; and Org. Rem. vol. i. plate viii. fig. 1—7. The reader will be amused by the perusal of the ingenious but unsuccessful attempt of the excellent author, Mr. Parkinson, to elucidate their nature. I have still a specimen which he presented to me more than thirty-five years since, as one of the most curious and perplexing fossils that had ever come under his notice.

† Pict. Atlas, pl. viii.

‡ See M. Brongniart's "*Tableau des Genres de Végét. Foss.*" p. 44.

§ Vide Geol. Proc. vol. ii. p. 438.

‖ Geol. Society, June 1852. Dr. Lloyd's specimens are probably referable to the genus *Walchia*: see *Lign.* 60.

SIGILLARIÆ AND STIGMARIÆ.

Among the most common and striking objects that arrest the attention of a person who visits a coal-mine for the first time, and examines the numerous vegetable relics that are profusely dispersed among the heaps of slate, coal, and shale, are long flat slabs, from half an inch to an inch thick, having both surfaces longitudinally fluted, and uniformly pitted with deep symmetrical imprints; these are disposed with such perfect regularity between the grooves, that the specimens are often supposed, by persons not conversant with palæontology, to be engraven stones, and not natural productions. These fossils are the flattened trunks of gigantic trees covered by the bark in the state of coal; the regular imprints on the surface, being the scars left by the separation of the petioles or leaf-stalks, as in the arborescent ferns previously examined. The name *Sigillaria*, commonly applied to these fossils, is derived from *sigillum*, a seal, and alludes to the regular and uniform pattern of the imprints on the surface. These stems are from a few inches to several feet in diameter, and the largest attain a height of sixty feet; they are generally found lying in a horizontal position in the strata, and quite flat, from the pressure produced by the superincumbent rocks; but when the trunks are in an erect position, and at right angles to the plane of the beds, the cylindrical form of the original is preserved.

A remarkable instance, in which five stems of Sigillaria were standing upright, with their roots in the soil below, apparently in the position in which they grew, was brought to light a few years since, in forming the Bolton and Manchester railway.* They stand on the same plane, and near

* These trees still remain *in situ*, and, thanks to the scientific zeal of Mr. Hawkshaw, have been carefully preserved. They are situated at Dixon Fold, Clifton, near Manchester. Instructive models of

to each other. Their roots are branched, and spread out in the bed of impure coal in which they are implanted. The trunks are surrounded by a soft blue shale. The largest tree is eleven feet high, and seven and a half feet in circumference at the base; its trunk is gnarled and knotted, and has many decorticated prominences, like those in barked timber of our old dicotyledonous trees; the roots, too, partake of the same character.* The others are respectively from three to five feet in height. A sketch of one of the

LIGN. 32. BASE OF A TRUNK OF A SIGILLARIA, WITH ROOTS, standing erect with five other stems, in Carboniferous strata.

(*The original is four feet high.*)

short stems is subjoined. All the trees were broken off as if by violence, and no traces of the upper part of the stems or branches were detected.

In the stratum through which the roots extend, a considerable quantity of the fossil cones, called *Lepidostrobi*, hereafter described, were imbedded (see *Lign.* 40). A thin layer of coal which invested the stems, was evidently the

these highly interesting relics of the carboniferous forests may be obtained.

An excellent Memoir on this discovery, with illustrations, by Mr. Hawkshaw, is given in Geol. Trans. vol. vi. pl. xvii. See Pict. Atlas, p. 198; and Petrifactions, p. 36.

* See Mr. Bowman's Memoir, Geol. Proc. vol. iii. p. 270.

carbonized bark. All the stems were filled with blue clay, or shale, a proof that they were hollow when submerged in the mud, which is now consolidated into the shale in which they are imbedded. But it is not probable that they were originally tubular, like a reed: on the contrary, there is evidence to show that they were highly organized. Their internal structure may have decayed, or been destroyed by insects or other depredators; as is often the case in tropical climates, where the trunks of timber trees are speedily excavated after their fall, and afford shelter to innumerable insects and reptiles, as the weary traveller often finds to his surprise and annoyance.* The late Mr. Bowman affirmed† that these trees were dicotyledonous, and stated that medullary rays and coniferous structure could be detected; an opinion, which the researches of M. Brongniart on the Sigillariæ have fully corroborated.

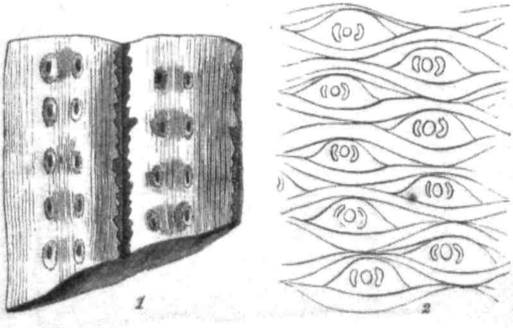
Many other instances have been noticed of Sigillariæ standing more or less erect in the strata. In forming the railway tunnel at Claycross, five miles south of Chesterfield, through the middle portion of the Derbyshire coal measures, in 1838, a group of nearly forty trees (*Sigillariæ*) was discovered, standing not more than three or four feet apart, at right angles to the plane of the strata.‡ On the coast of Northumberland, within the length of half a mile, twenty trees were observed by Mr. Trevelyan, in 1816 (*Bd.* p. 470). The coal-pit at St. Etienne, in France, described by M. Alex. Brongniart, is celebrated for affording an example of this phenomenon (*Wond.* p. 673); but the positions of many of those stems are inclined at various angles, and their roots implanted in different beds, so that the perpendicularity of the erect trees is probably accidental (*Bd.* p. 471).

The most remarkable instance hitherto observed, is on the

* Mr. Hawkshaw, Geol. Proc. p. 269. † Geol. Proc. vol. iii. p. 270.
‡ Ibid. p. 272.

southern shore of the Bay of Fundy, in Nova Scotia, where the cliffs, which are about two hundred feet high, are composed of carboniferous strata, consisting of coal, clay, grit, and shale, in which numerous erect trees, probably Sigillariæ, are seen on the face of the cliff; there are ten rows one above another, indicating, in the opinion of Sir C. Lyell, repeated subsidences of the land, so as to allow of the growth of ten successive forests!* (*Wond.* p. 674).

The stems of Sigillariæ vary in size from a few inches to five feet in diameter; and in length from five to sixty feet; they gradually taper from the base to the summit. A spe-



LIGN. 33. SIGILLARIÆ; *in Coal-shale.*

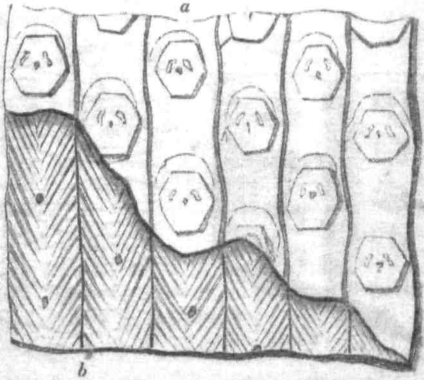
Fig. 1.—A specimen deprived of its carbonaceous bark, except in the interstices of the channels, and showing pits left by the external scars.

2.—The markings of S. DEFRANCII. (*Vég. Foss. Br.*)

cimen measured by M. Brongniart was forty feet long, one foot in diameter at the base, and but six inches at the top, where it divided into two equal branches. These stems may be readily distinguished from those of other trees with

* "On the Coal Strata of Nova Scotia." Amer. Journ. Oct. 1843; and Travels in America, vol. ii. p. 180.

which they are associated, by the fluted surface produced by the deep longitudinal grooves, and the regularly disposed imprints between the channels.* The carbonized bark, in large specimens, is often an inch thick, but in small examples is a mere pellicle, and being extremely brittle, flakes off with the slightest touch, leaving the inner surface exposed, with the coal remaining in the deep furrows and pits, as in *Lign.* 33, *fig.* 1. No traces of leaves, or fruit, in connexion with the stems, have been observed. The subjoined sketches (*Lign.* 33, and 34,) illustrate the usual aspect of these fossils. The difference between the im-



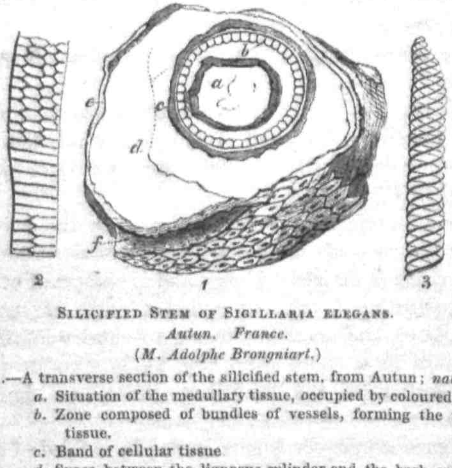
LIGN. 34. SIGILLARIA SAULLII.
Carb. Manchester.

a. The imprints of the petioles on the external surface of the carbonized cortical investment.
b. The inner surface, exposed by the removal of the crust or bark.

prints on the outside of the bark, and those on the exposed surface of the stem, from the removal of the cortical covering, is well marked in *Lign.* 34.

* The stems of some recent dicotyledonous trees from New Zealand, in the possession of Dr. Robert Brown, possess similar longitudinal ribs and furrows, both on the bark and alburnum, or naked wood.

INTERNAL STRUCTURE OF SIGILLARIÆ.—Our knowledge of the structure of this numerous tribe of plants, has received an important accession by the discovery of the silicified fragment of a stem, which, fortunately for the advancement of science, was placed at the disposal of M. Adolphe Brongniart. It has been described and illustrated by that eminent botanist, in a memoir which is one of the most valuable contributions to fossil botany that has hitherto appeared.*



LIGN. 35. SILICIFIED STEM OF SIGILLARIA ELEGANS.
Autun. France.
(*M. Adolphe Brongniart.*)

Fig. 1.—A transverse section of the silicified stem, from Autun; *nat.*
- *a.* Situation of the medullary tissue, occupied by coloured silex.
- *b.* Zone composed of bundles of vessels, forming the woody tissue.
- *c.* Band of cellular tissue
- *d.* Space between the ligneous cylinder and the bark, with no evident structure, but originally occupied by the external cellular tissue.
- *e.* Zone of indistinct cellular substance.
- *f.* External cortical envelopment, or bark.

2.—Portion of one of the vessels of the medullary tissue, as seen in a longitudinal section. (× ×.)

3.—Portion of a spiral vessel of the same tissue. (× ×.)

The annexed figure (*Lign.* 35) is an outline of the specimen, of the natural size; but this sketch is a mere plan or

* The reader intending to make fossil botany his particular study, should refer to the original memoir, and become familiar with the

diagram, for it is impossible without the aid of colour to convey a faithful idea of the original. The student should observe, that when mineral matter has permeated the stems of plants, the vascular tissue is often so well preserved, that one such specimen affords more important information, than hundreds of examples in which the form alone remains.

The external surface of this specimen possesses the characteristic markings of the insertion of the leaf-stalks of *Sigillaria elegans.* The internal organization, as seen in the transverse section, is as follows :—

a. The centre, filled with silex ; it exhibits no traces of structure.

b. The zone which surrounds the interspace on which this letter is placed, is composed of bundles of vascular tissue. A portion of one of these bundles, highly magnified, is represented in *Plate V. fig.* 7.

The *inner* circle of this zone, indicated by the *convex undulating line,* is made up of medullary vascular tissue ; the external circle is divided by rays, and is composed of woody fibre, constituting a ligneous cylinder. One of the spiral vessels (*fig.* 3), and another showing a remarkable difference of structure in a short space (*fig.* 2), as seen in a longitudinal section of the medullary tissue, are figured in *Lign.* 35.

The ligneous cylinder is surrounded by a band of cellular tissue, and the space between this and the cortical integument is occupied by silex, in which there are but obscure traces of structure.

The inner layer of bark, *f,* is composed of elongated cells,

facts and inferences so admirably enunciated by the author ; not only for the illustration of the structure of the tribe of plants under consideration, but as a valuable exemplification of the manner in which all such inquiries should be conducted. See *Archives du Muséum d'Histoire Naturelle,* tom. i. Paris, 1839.

disposed in a radiating manner, and traversed by fibro-vascular bundles, which pass towards the leaves.

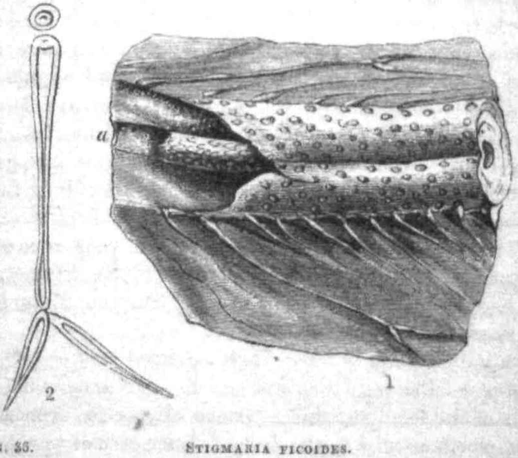
Upon instituting a comparison between the fossil and the stems of those recent plants which present the closest analogy to it, M. Brongniart was led to conclude that the Sigillariæ constituted a peculiar extinct family, belonging to the great division of gymnospermous dicotyledons.

The Sigillariæ were tall erect trees, with a regular and cylindrical stem, without side branches, but dichotomous towards the summit. Their superficial bark was hard and durable, channelled longitudinally, bearing leaf-scars that are of a rounded form above and below, and angular at the sides, often oblong in relation to the stem, and having three vascular pits, one central and small, and two lateral of a larger size. The internal structure bears most analogy to that of the Cycadeæ, and the foliage consisted of long linear carinated leaves. The Sigillariæ, therefore, differ essentially from the arborescent cryptogamia, which they somewhat approach in having scalariform vascular tissue, symmetrical and regular leaf-scars, and branchless trunks. More than fifty species have been determined.*

STIGMARIA. *Lign.* 36.—This extended notice of the structure of the Sigillariæ, will enable us to understand the nature of the fossil vegetables termed *Stigmariæ*, or spotted-stems, which abound in the beds of under-clay of most coal-fields, as stated in a former part of this work (*ante*, p. 81). These bodies when uncompressed are of a cylindrical form, from one to six or seven inches in diameter, and of considerable length—sometimes upwards of twenty feet—and gradually diminish in size towards their termination. The surface is marked with distinct pits or areolæ, of a circular or oval form, with a small tubercle in the centre of each, disposed around the stem in a quincunx and somewhat regular order.

* For figures of Sigillariæ, see Pictorial Atlas, pl. xix. xx. xxiv.

When broken transversely, a small cylindrical axis is seen to extend in a longitudinal direction through the stem, like a medullary column ; it seldom occupies the centre, but lies near to one side, and parallel with a depression on the outer surface of the fossil. This internal body is often loose, and removable ; its surface is covered with interrupted, irregular, longitudinal, ridges, which leave corresponding depressions



LIGN. 35. STIGMARIA FICOIDES.

Carboniferous. Derbyshire.—¼ *nat.*

Fig. 1.—Portion of a stem, with some of the rootlets (formerly considered as leaves) extending into the surrounding clay. The internal axis is seen at *a*; and the corresponding groove on the portion of external surface that remains.

2.—An outline of one of the rootlets, with a tubercle to show the mode of its attachment by a ball and socket joint to the root.

on the walls of the cavity in which it was inclosed. *Lign.* 36, represents a fragment exhibiting the characters above described.

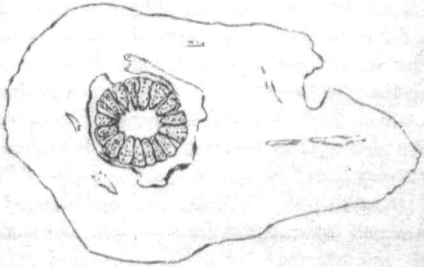
When Stigmariæ are observed in the under-clay, to which stratum they are principally confined, long, tapering, sub-cylindrical fibres, often several feet in length, are seen affixed to the tubercles with which the surface is covered; their form and mode of attachment are shown in *Lign.* 36. Instances occur in which several Stigmariæ spring from a common centre, of a dome-like form, whence they radiate in every direction (*Bd.* pl. lvi. fig. 8), and the main branches divide and subdivide till they are lost in the surrounding rock.

The nature of these fossil vegetables was long a perplexing question, for no specimens had been found in connexion with any of the stems, branches, or foliage, that abound in the coal deposits. At length, the discovery of a dome-shaped mass, to which were attached numerous Stigmariæ, seemed to afford a clue to the solution of this botanical problem; and it was concluded by the eminent authors of the "Fossil Flora of Great Britain," that the original belonged to a tribe of plants which inhabited swamps, or still and shallow lakes, and were characterized by a low truncated stem, having long horizontal branches beset with cylindrical, and, probably, succulent leaves, that either trailed on the surface of the swamp, or floated in the water.

But within the last few years, the occurrence in various carboniferous deposits of erect stems of Sigillariæ, has shown that the Stigmariæ are nothing more than the roots of these and other congenerous trees; an opinion maintained by the Rev. H. Steinhaur more than thirty years ago, and subsequently affirmed by M. Adolphe Brongniart, who found, on examining microscopically the internal structure of a silicified specimen in which the vascular tissue was preserved, that it bore as close an analogy to that of the Sigillariæ, as exists between the roots and trunks of certain dicotyledonous trees.

The annexed figure, *Lign.* 37, represents the transverse section of a small Stigmaria, with the axis displaced from its natural situation; this circumstance, as well as the corresponding external groove, has arisen from compression, by which the tough cylinder has been forced from its original position in the middle of the soft cellular tissue, to one side.

The central axis is thus shown to be a cylinder composed of bundles of vessels, disposed in a radiating manner, and



LIGN. 37. TRANSVERSE SECTION OF STIGMARIA FICOIDES; *nat.*

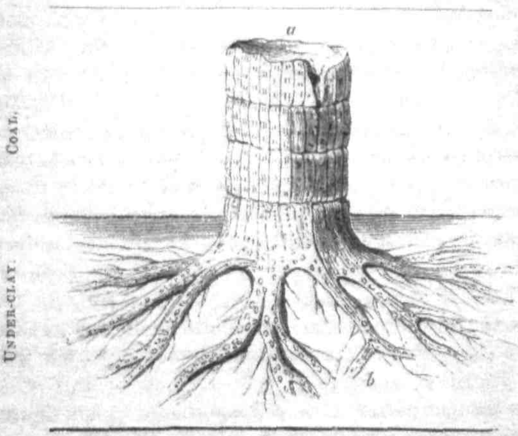
(*M. Adolphe Brongniart.*)

This specimen shows that the cylinder (*a* in *Lign.* 36) is formed of bundles of vascular tissue, disposed in rays.

separated from each other by medullary rays; the whole constituting a ligneous zone resembling that of *Sigillaria* (see *Lign.* 35); but the inner circle of medullary tissue seen in the latter is altogether wanting. This difference is similar to that observable in the stems or branches of a dicotyledonous tree, in which the woody cylinder is associated internally with bundles of medullary tissue, and the roots of the same tree that are destitute of them. Part of a vascular bundle from the woody tissue of a Stigmaria, seen

by a high power and transmitted light, is figured *Pl. V. fig.* 6; the smooth interspaces are composed of cellular tissue.

This opinion of M. Brongniart was confirmed by the discovery, in 1843, at St. Helen's, near Liverpool, of an upright trunk of a Sigillaria, nine feet high, with ten roots



LIGN. 38. ERECT STEM OF A SIGILLARIA, WITH ROOTS.

Coal Mine, near Liverpool.

a. The trunk of the tree, traversing a bed of Coal.
b. The roots (*Stigmariæ*) spreading out in the Under-clay.

eight or nine feet in length, still attached, and extending in their natural position. *These roots are undoubted Stigmariæ of the usual species, S. ficoides; and the radicles, formerly considered leaves, are spread out in all directions, to the extent of several feet.** To the sagacity and perseverance of Mr. Binney, of Manchester, science is indebted for this important

* From a communication to the British Association at Cork, 1843.

discovery; the same gentleman laid bare, on the floor of the mine at Dunkinfold, near Manchester, a large erect trunk of a Sigillaria, with numerous Stigmariæ roots.

In the Pictou coal-field of Cape Breton, in Nova Scotia, similar facts have been brought to light; the remarkable phenomena existing in that locality, of successive carboniferous deposits containing scores of erect trees with roots spreading into their native soil, presenting peculiar facilities for verifying the observations made in England. In an interesting memoir on the coal-fields of Nova Scotia, Mr. Richard Brown has given a detailed account of numerous examples of stems of Sigillariæ, and of Lepidodendra, (a tribe of gigantic club-mosses of which we shall presently treat,) with the roots attached; these roots, in every instance, had the characters and structure of Stigmariæ. In one instance, the stem of the tree was broken off close to the roots, and the hollow cylinder of bark was bent down and doubled over by the pressure of the surrounding mud, so as effectually to close up the aperture, and leave only a few irregular cicatrices converging near the apex; this fossil explains the true nature of the "dome-shaped" plant figured in the Fossil Flora, and in Dr. Buckland's Essay.*

Lepidodendron, (*scaly-tree*). *Lign.* 39.—Stems cylindrical, covered towards their extremities with simple, linear, or lanceolate leaves, which are attached to elevated rhomboidal spaces, or papillæ; papillæ marked in the upper part with a large transverse triangular scar; lower part of the stem destitute of leaves.

The remains of this tribe of plants abound in the coal formation, and rival in number and magnitude the Calamites and Sigillariæ previously described. These trees have received the name of *Lepidodendra*, from the scaly character

* See Pictorial Atlas, p. 200: and Petrifactions, pp. 37, 38.

of their stems, occasioned by the angular scars left by the separation of the foliage, as is the case in arborescent ferns:

LIGN. 39. Fig. 1.—A TERMINAL BRANCH OF A LEPIDODENDRON; *nat.*
2.—Leaf-scars on the stem of a Lepidodendron; *nat.*
In Coal-shale, Newcastle.

the term, however, simply indicates the appearance, for the surface is not imbricated. Some of these trees have been found almost entire, from the roots to their topmost

branches. One specimen, forty feet high, and thirteen feet in diameter at the base, divided towards the summit into fifteen or twenty branches, was discovered in the Jarrow coal-mine.* The foliage consists of simple, linear leaves, spirally arranged around the stem, and appears to have been shed from the base of the tree with age. The scars produced by the attachment of the petioles were persistent; and the twigs and branches are generally found covered with foliage, as in *Lign.* 39. The roots are Stigmariæ, like those of the Sigillariæ, as proved by specimens in the Pictou coal-field, discovered by Mr. Brown.†

The internal organization of the stem of Lepidodendron differs from that of Sigillaria, in the absence of the woody cylinder and medullary rays which constitute so peculiar and important a character in the latter. The Lepidodendra have only an eccentric, vascular, medullary zone, the interval between which and the bark is filled up by cellular tissue.‡ In their structure, external configuration, mode of ramification, and disposition of the leaves, they accord so closely with the *Lycopodiaceæ*, that, notwithstanding the disparity in size, M. Brongniart, Dr. Joseph Hooker, and *other eminent botanists, concur in regarding them as gigantic* arborescent club-mosses § The living species of Lycopodiaceæ amount to nearly two hundred, the greater number of which, like the arborescent ferns, inhabit the islands of intertropical regions. They are diminutive plants, with delicate foliage, none exceeding three feet in height; most

* Wond. p. 722. This specimen is figured and described in Foss. Flor.

† Petrifactions, p. 39.

‡ See M. Ad. Brongniart, Archives du Muséum d'Hist. Nat. tom. i. (for 1839), pl. xxx.

§ Figures of Lepidodendra in Wond. p. 718. Pict. Atlas, pl. i. iii. ix. xxvi. xxvii. xxxiii.

of them trail on the ground, but there are a few erect species, one of which (*Lycopodium densum*) is abundant in New Zealand.

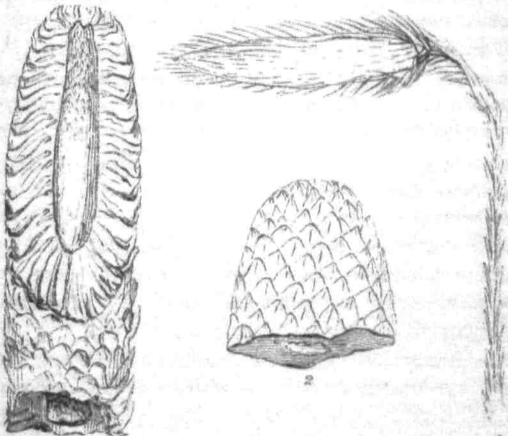
The fruit of the Club-mosses is an oval or cylindrical cone, which in some species is situated at the extremity of the branches, and constitutes an imbricated spike. Now associated with the stems of the Lepidodendra, and very often in masses of their foliage, and in some instances attached to the extremities of the branches, are numerous oblong, or sub-cylindrical, scaly cones, garnished with leaves. These have received the names of *Lepidostrobi* (scaly-cones), and are unquestionably the fruit of the trees with which they are imbedded.

LEPIDOSTROBUS. *Lign.* 40.—A cylindrical strobilus or cone, imbricated from above downwards, composed of winged scales, terminating in rhomboidal discs: the axis traversed by a longitudinal cavity or receptacle.

These fossils have long been known to collectors, and are figured by Martin (*Petrif. Derbiensia*), Parkinson (*Org. Rem.* vol. i. pl. ix.), and others. They are cylindrical imbricated bodies, rounded at both extremities, from two to six or seven inches in length, and one or two inches in circumference. When broken asunder, a cylindrical cavity is exposed, which is sometimes hollow, but commonly filled with mineral matter; and when specimens are found imbedded in shale, the cone is fringed with linear-lanceolate bracteæ, as in *Lign.* 40, *fig.* 3. These fruits, like the fronds of ferns, often form the nuclei of ironstone nodules, and the leaves are frequently replaced either by a white hydrate of alumine, or by the mineral called galena, or sulphuret of lead, and the receptacles filled with the same substances. The specimens from Coalbrook Dale are generally in this state of mineralization, and possess great brilliancy; they are interesting examples of the electro-chemical changes

which these fruits of the carboniferous forests have undergone.*

The figures in *Lign.* 40, represent the usual characters of these fruits. Of the young specimen, (*fig.* 3,) situated at the



LIGN. 40. LEPIDOSTROBI, THE FRUIT OF LEPIDODENDRA; *nat.* *Coalbrook Dale.*

Fig. 1.—A portion of a cone, showing the imbricated structure and internal cavity.
2.—The upper part of a cone, displaying the imbricated surface.
3.—A young specimen attached to the extremity of a branch.

termination of a branch, M. Brongniart observes, "qu'il est impossible de ne pas reconnaître pour un Lepidostrobus

* These fossil cones are not liable to decompose, like the pyritous fruits from the Isle of Sheppey; they require no preparation for the cabinet; washing injures their lustre; a soft brush will safely remove any extraneous matter. There is a fine collection of Lepidostrobi in the British Museum; see Petrifactions, p. 42.

jeune, fixé à l'extrémité d'un rameau."* As it is only in their young state that the spikes are found attached to the branches, it is probable they were shed as soon as they arrived at maturity.

Triplosporite.—Additional light has recently been thrown on the structure of the Lepidostrobi, by Dr. Robert Brown's examination of a silicified specimen of the upper part of a strobilus, in which the internal organization is beautifully displayed. The reader specially interested in this department of fossil botany should refer to the original memoir by the illustrious President of the Linnæan Society, with the accompanying plates that admirably exhibit the microscopic analysis of the structure of this remarkable fossil; a slice of which was shown me some years since by the late Marquis of Northampton.† The external surface of the specimen is covered with hexagonal areolæ; the transverse sections exhibit the appearance of the bracteæ and sporangia. The strobilus is formed of a central axis of relatively small diameter, from which proceed bracteæ, about thirteen in number, that are densely approximated, and much imbricated; and of an equal number of sporangia, filled with innumerable microscopic sporules, originally connected in threes. This triple composition of sporules (which differs from the constant quadruple union in the tribes of existing plants presumed to be most nearly allied to the fossil, namely the *Ophioglosseæ* and *Lycopodiaceæ*) is expressed by the name *Triplosporite*, adopted by Dr. Brown to indicate this peculiarity of structure, and the class or primary division to which the original plant is supposed to belong.‡

* Hist. Vég. Foss. tom. ii. p. 47.

† The specimen brought to England was but two inches of the upper end of the cone; it was purchased conjointly by Lord Northampton, Dr. Brown, and the British Museum, for 30*l.*!

‡ See Trans. Linnæan Society of London, vol. xx. p. 469.

Lycopodites.—Species of true Lycopodiaceæ occur in tertiary marls; a beautiful specimen, from Germany, *Lycopodites Benettiæ*, is figured *Wond.* p. 723.

HALONIA; KNORRIA. *Lign.* 41.—Associated with the plants already described from the coal-measures, there are trunks and branches of other trees, presenting peculiar and but imperfectly known characters, which it will be convenient to notice in this place. Fragments of these stems are to be seen in most public collections of the carboniferous flora, and should be examined by the student, for figures and descriptions can convey but an imperfect idea of their nature.

Mr. Denny, the intelligent and indefatigable Curator of the Leeds Philosophical Society, has given the following admirable summary of the distinctive characters of the stems of most frequent occurrence in the Coal,* which will be found a useful guide to the collector.

1. *Sigillaria.* — Stem furrowed, not branched, leaf-scars small, *round*, much *narrower* than the ridges of the stem.

2. *Favularia.*—Stem furrowed, not branched, leaf-scars small, *square*, and as *broad* as the ridges of the stem.

3. *Lepidodendron.* — Stem not furrowed, branched, covered with lozenge-shaped scars in quincuncial order, each having a papilla in the upper part; the upper portion of the stem and branches with simple linear leaves; the lower portion destitute of leaves.

4. *Halonia.*—Stem not furrowed, branched, covered with indistinct rhomboidal marks, and tubercular projections disposed in quincunx.

5. *Knorria.*—Stem not furrowed, branched, marked with projecting scars of petioles disposed spirally.

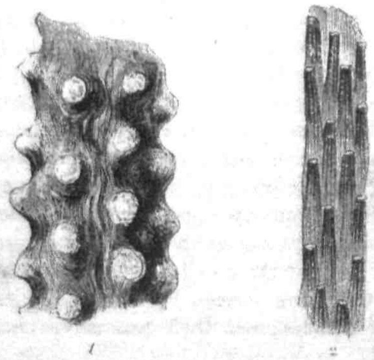
* On the Fossil Flora of the Carboniferous Epoch, with especial reference to the Yorkshire Coal-field. By Mr. Henry Denny, A.L.S. Proceedings of the Polytechnic Society of Yorkshire; for 1850.

6. *Megaphyton.* — Stem dotted, neither furrowed nor branched, leaf-scars very large, of a horse-shoe figure.*

7. *Bothrodendron.* — Stem pitted, neither furrowed nor branched, scars of cones (?) obliquely oval.

8. *Ulodendron.*—Stem neither furrowed nor branched, covered with rhomboidal marks; scars of cones (?) circular.

The characters of the roots called *Stigmariæ* (*ante*, p. 134), and of the stems named *Calamites* (*ante*, p. 107), and *Equisetites* (*ante*, p. 106), are sufficiently distinct from the above to be easily recognized. I will briefly notice those not previously described.



LIGN. 41. STEMS FROM THE COAL FORMATION.

Fig. 1.—HALONIA REGULARIS. *Coalbrook Dale.*
2.—KNORRIA TAXINA. *Roof of the High-main Coal seam, Jarrow Colliery.* (*Brit. Foss. Flor.*)

Halonia.—The specimens usually seen are mere sandstone casts having a thin carbonaceous crust; the stem is branched and beset with large elevated knobs, or subcortical protuberances, as shown in *fig.* 1, *Lign.* 41. These

* Pictorial Atlas, pl. xxv.

plants appear to be closely related to the Lepidodendra; their mode of branching is shown in a beautiful specimen (in the museum of the Leeds Philos. Soc.) figured and described by Mr. Denny, which is also remarkable because it indicates the probability that the Haloniæ, and the fossil stems, termed Knorriæ, are identical; for the specimen in question, which in its branches is unquestionably of the former type, has the base of the stem impressed with the leaf-scars of the latter.

Knorria.—To this genus the authors of the Fossil Flora of Great Britain referred those stems which have projecting leaf-scars, arranged spirally. The beautiful specimen figured as *Knorria taxina, Lign.* 41, *fig.* 2, closely resembles a young branch of Yew (*Taxus*), and perhaps might be more correctly named *Taxites.*

Bothrodendron and Ulodendron.—These genera, together with *Megaphyton*, are stems of a very remarkable character, and are easily distinguished by the vertical rows of large and distant scars. The two first have two series of very deep oval depressions on opposite sides of the stems, arranged alternately in the specimens I have examined: from the size and form of these obliquely-oval cavities, it is supposed that they were formed by the attachment of cones, and not by petioles; but their real nature is involved in obscurity.*

In *Megaphyton*, the large ovate scars indicate the attachment of deciduous branches or gigantic leaves, which did not grow all round the stem, but in a regular order of superposition on each side.†

ASTEROPHYLLITES.—I shall conclude this notice of some of the most characteristic trees of the Carboniferous Flora, with an account of a tribe of plants whose remains are so

* Figured in Bd. pl. lvi. † Figured in Pict. Atlas, pl. xxv.

common in the coal-shales and grits, that there are but few large slabs with vegetable remains that do not exhibit examples of the elegant verticillate foliage of one or more species. The term *Asterophyllites*, (expressive of the star-like form of the leaves,) applied to this family by M. Ad. Brongniart, includes several fossil plants which are known to geologists under different generic names; the following concise account may be useful to the student.*

1. *Calamodendron.*—These are arborescent stems, ligneous internally, and covered with a smooth carbonaceous crust, without regular longitudinal striæ, and not articulated; but the woody axis covered by this bark is deeply striated and articulated, resembling in this respect the true Calamites. These stems have a large central pith, or medullary column, surrounded by a ligneous zone, which is formed of radiated bands, without circles of growth: the structure of the carbonized bark is unknown.

2. *Asterophyllites.*—These are supposed to be the branches and foliage of the stems above described.

3. *Sphenophyllum.*—Plants, differing in the form of the leaves, but analogous in structure and mode of fructification to the Asterophyllites.

4. *Annularia.*—Herbaceous aquatic plants, distinct from the preceding.

5. *Volkmannia.*—These fossil plants are Asterophyllites in fructification.

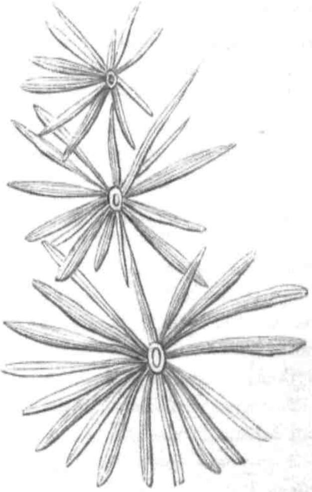
The *Asterophyllites* (*Lign.* 42) had branched articulated stems, with verticillate leaves, arranged perpendicularly to the branches which supported them: but as the foliage is in most instances partially concealed, the natural form is but seldom observable.

The original plants are supposed to have been a tribe of

* Consult *Tableau des Genres de Végétaux Fossiles*, par M. Ad. Brongniart. Dict. d'Hist. Nat. Paris, 1849.

flowering dicotyledons, for small seed-vessels resembling those of the Cypress are often found with the foliage.

The *Annulariæ* were herbaceous plants with verticillate foliage like the former, but the whorls were arranged on the same plane with the stems on which they grew, and their remains have a very elegant appearance when expanded in the coal schists. It is supposed that they were aquatic plants, and that the stems and leaves floated on the surface of the water.*



Lign. 42.
Asterophyllites equisetiformis; *nat.*
Coal-shale. (*Foss. Flor.*)

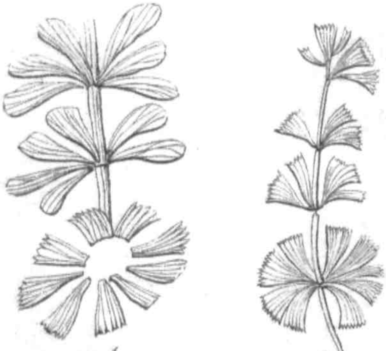
Sphenophyllum (*wedge-shaped leaf*). *Lign.* 43. —The fossil vegetables thus named, though somewhat resembling in their elegant verticillate foliage the Asterophyllites, differ essentially, and are regarded by M. Brongniart as herbaceous plants related to the *Marsiliaceæ*, or Pepper-worts. The leaves are triangular, truncated at the summit, and very deeply lobed and dentated. The fructification consists of sessile axillary or terminal spikes, composed of verticillate bracteæ, covering the receptacles. This mode of fructification resembles that of the Asterophyllites.†

Cardiocarpon.—*Lign.* 44. *fig.* 1.—These are small fossil

* Wond. p. 717. Petrifactions, pp. 27, 43, &c. For coloured figures see Pictorial Atlas, pl. v.

† For details consult *Tab. des Genres de Vég. Foss.* p. 52.

fruits or seed-vessels, which much resemble those of the Thuya or *Arbor Vitæ*, and are so often found imbedded with



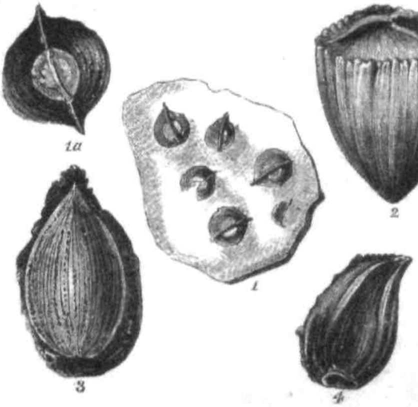
LIGN. 43. Fig. 1.—SPHENOPHYLLUM SCHLOTHEIMI; *nat.*
2.—SPHENOPHYLLUM EROSUM.
Coal-Shale.

masses of the foliage of Asterophyllites, that it is conjectured they belong to those plants. They occur in groups of from five to twenty, and evidently were *didymous*, *i.e.* grew in pairs. *Fig.* 1*a.* is an enlarged view, to show the surface left by the attachment of the twin-seed.

TRIGONOCARPUM. *Lign.* 44. *figs.* 3. 4.—These fruits, which resemble those of certain Palms, are often met with in the coal-mines of Leicestershire and Yorkshire; frequently occurring in groups of thirty or forty, as if they were the scattered seeds of a raceme of a Palm: they are referred to the genus *Nœggarathia*, a tree of the carboniferous formation allied to the Palms.

A figure of a fossil fruit from the Oolite—*Carpolithes Bucklandi*, is introduced in *Lign.* 44, *fig.* 2, and will be described hereafter.

The reader will observe that the fossil vegetables hitherto described belong, with but few exceptions, to the Carbonife-



LIGN. 44. FOSSIL FRUITS, OR SEED-VESSELS; *nat.*

Fig. 1.—CARDIOCARPON ACUTUM. *Snibstone Coal-mine, Leicestershire.*
1a.—One of the above magnified.
2.—CARPOLITHES BUCKLANDII. *Coralline Oolite, Malton.*
3.—TRIGONOCARPUM OLIVÆFORME. *Snibstone Colliery.*
4.—TRIGONOCARPUM NÖGGERATHI.

rous flora; and that the remains of Ferns, Calamites, Sigillariæ, and Lepidodendra, compose in a great measure those prodigious accumulations of mineral fuel, or coal, which supply the luxuries and necessities created by civilization.

Our review of fossil plants will now assume somewhat of a botanical arrangement, and we proceed to notice some of the most characteristic vegetable forms of the secondary and tertiary formations. We commence our examination with those remarkable tribes of gymnosperms, the Cycadaceæ, which comprise the Zamiæ and Cycadeæ.

FOSSIL CYCADACEÆ.

The plants of this subdivision of the vegetable kingdom, from their singular structure and mode of growth, their simple cylindrical stems, and coronets of pinnated foliage, resembling that of certain palms, their usually gyrate vernation like that of the ferns, and their anomalous inflorescence and fructification, are objects of great interest to the scientific botanist; while the abundance of their fossil remains in the secondary formations renders them of the highest importance to the geologist.

As many kinds of Zamia* and Cycas are cultivated in our hot-houses, the general appearance of the plants of this order must be familiar to the reader: the annexed figure of a beautiful living Cycas in the Royal Gardens at Kew, will serve to illustrate the general aspect of these exotics.

LIGN. 45.
FOLIAGE AND UPPER PART OF THE STEM OF CYCAS REVOLUTA. $\frac{1}{12}$ *nat.*
In Kew Conservatory.

The Zamiæ are short plants, with stout cylindrical stems, beset with thick scales, which are the bases of the petioles that have been shed: towards the summit the stem is garnished with a crown of elegant leaves; the fruit resembles the cones of pines. The leaves are pinnated, and very tough; their venation is either parallel as in endogens, or dichotomous as in ferns, but never reticulated as in exo-

* The Linnæan genus Zamia is now separated into five or six genera, as Encephalartos, Macrozamia, Dion, &c.

gens: in a young state they are coiled up like a crosier, as in ferns.

The Cycadeæ have the general aspect of the Zamiæ, but differ in their fructification and other characters; and some species have the stem bifurcated towards the top, and attain a height of upwards of twenty feet; for example, *C. circinnalis.*

The stem in its internal structure* bears a close analogy to that of the Coniferæ; it has a central medullary column surrounded by a ligneous cylinder, divided by cellular medullary rays, each composed of bundles of vessels, and a thick cellular cortical investment or false bark,† composed of the persistent scales that formed the bases of the petioles. (See *Pl. V. fig. 5.*)

The existing species of Cycadaceæ are exclusively natives of hot regions, and chiefly inhabit the West Indies, South Africa, Equinoctial America, Japan, New Holland, &c.; not one species is known in Europe: a fact in striking contrast with the abundance of fossil plants of this order, which occur throughout the secondary formations of England and the continent.‡

No true cycads have hitherto been discovered in the carboniferous deposits; it is in the floras of the secondary epochs, from the new Red to the Cretaceous inclusive, that this tribe of plants forms an important feature. The foliage, stems, and fruits, occur in a fossil state; and as these organs cannot be referred with certainty to their respective plants, distinct genera are formed for their reception.

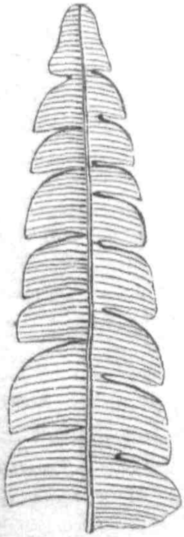
Foliage.—From the tough and durable nature of the leaves, the foliage of the Cycadeæ occurs in a fine state of

* See *Bd.* pl. lxii.

† See *Bd.* vol. i. pp. 494—498, for detailed description of structure in recent and fossil Zamiæ and Cycadeæ.

‡ The most interesting collection of living Cycadeæ and Zamiæ near London, is that of James Yates, Esq., of Lauderdale House, Highgate; it comprises choice examples of several of the sub-genera into which these plants are now divided by botanists.

preservation; and in the fluvio-marine deposits of the Oolite of Yorkshire, many specimens of great beauty have been collected. I know not another locality in England so rich in fossils of this kind, as the cliffs along the coast near Scarborough; Gristhorpe Bay is well known to collectors. Not only the leaves, but also the fruits or cones occur, and of these, examples are to be seen in most public museums.* The leaves are carbonized, but the venation is well preserved.



LIGN. 46. Part of a leaf of PTEROPHYLLUM COMPTUM; *nat.* *Oolite, Scarborough.*

The leaflet of the recent Cycas is distinguished by a strong nervure, which runs along the middle; that of Zamia has no mid-rib, but fine parallel veins that pass direct to the margin.

PTEROPHYLLUM COMPTUM. *Lign.* 46.—The general aspect of these fossils is shown in this figure of a leaf, referred to the genus *Pterophyllum*, which is characterized by leaflets, often slightly united at their base, truncated at the summit, of a quadrangular or oblong form, and having fine, straight, parallel veins. The leaves are ten or twelve inches long, and have fine lanceolate leaflets; they are abundant in the same beds, and are often associated with the cones or fruit† figured in *Lign.* 48.

ZAMITES PECTINATUS. *Lign.* 47.—In the Stonesfield slate, collocated with remains of reptiles, fishes, insects, and mollusks, leaves and fruits of cycads are occasionally met with.

* British Museum: see Petrifactions, p. 54, Room 1, Case F.
† Brit. Mus. Petrifactions, p. 55.

A portion of a leaf nine inches long is here figured. The Lias of Dorsetshire has yielded many beautiful relics of this family.*

But few vestiges of the foliage of Cycads have been observed in the Wealden formation of England; one elegant leaf, however, of an undescribed species, was obtained some years since, from a sandstone quarry in Surrey, and is figured in my Geology of the South-east of England, p. 238; it is named in honour of my distinguished friend, M. Ad. Brongniart, *Cycadites Brongniarti.* The Wealden of the north of Germany is very rich in fossil Cycadeæ; my friend, Dr. Dunker, has figured and described twelve species in his admirable work on the organic remains of that formation.†

LIGN. 47. Part of a leaf of ZAMITES PECTINATUS; *nat.* *Oolite, Stonesfield.*

Fruits.—The cones or fruits which occur with the foliage of Zamiæ in the carbonaceous shales and marls of the Oolite of the Yorkshire coast, are very fine, and have been described under the various names of *Zamites Mantelli, Z. gigas,* and *Z. lanceolatus.*

An interesting memoir on the structure of these fossils, by James Yates, Esq. (a gentleman distinguished for his knowledge of the recent Cycadaceæ), is published in the

* In the carboniferous strata of Eastern Virginia, United States, which are referred by Professor Rogers to the Oolitic epoch, leaves of Cycadeous plants are abundant. See Trans. American Geologists, p. 298.

† Mon. Norddeutschen Weald. tab. i. to vii.

Proceedings of the Yorkshire Philosophical Society for 1849, p. 37; and another communication on the same subject by my friend Professor Williamson, of Manchester, in *York. Phil. Trans.* 1819, p. 45; to these papers I must refer for a detailed account of all that is at present known respecting their organization.

ZAMITES MANTELLI.* *Lign.* 48.—The leaves associated

LIGN. 48. FRUIT OF ZAMITES MANTELLI, (*Brongniart*); *nat.*
From near Scarborough.
The surface of the cone is concealed by the bracteæ.

with the fruit here figured, have lanceolate leaflets that insensibly contract at the base, and are inserted obliquely

* *Podozamites* of Braun.

into the rachis; thus resembling the foliage of the recent *Encephalartos*. With these leaves, and the ovate cones (*Lign.* 48), are occasionally found a circle of leaves or elongated scales, locally termed "*collars*," which Professor Williamson has shown to be a zone formed by a scaly bud in which the germ of the plants was inclosed. In the progress of development, the fruit burst through the upper part of the investing sheath, and, as it grew to maturity, rose above the incurved elongated bracteæ, till the latter formed a zone or "collar" around the pedicle of the cone.* These fossils have been mistaken for flowers.†

It does not appear that the structure of the cone has been preserved in any of the specimens, so as to demonstrate the characters of the original; in all those I have examined, the surface of the fruit is concealed by the elongated bracteæ, which are pressed flat, and adhere so firmly to the inclosed body, as to render it impossible to ascertain its nature.‡ Mr. Williamson is of opinion that the plant resembled the recent Cycas circinalis, in its great height, and lax habits; and states, that he had seen portions of leaves that were three feet in length.

Zamites crassus. *Lign.* 49, *fig.* 1.—In Sandown Bay, on the south coast of the Isle of Wight, where the Wealden beds rise to the surface from beneath the lowest strata of Greensand on the east and west, several cones have been found, associated with other vegetable remains, and bones of the Iguanodon, &c. A fossil cone from this locality is here figured; it bears considerable resemblance to the fruit of the recent *Encephalartos*.

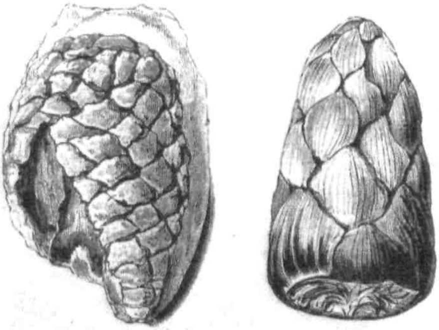
Zamites ovatus. *Lign.* 49, *fig.* 2.—A few examples of cycadeous fruits have been collected from the Greensand of Kent and Sussex. The beautiful fossil represented, *Lign.* 49, *fig.* 2, from Foss. Flor. is referred to the Zamiæ, by

* Proc. Yorkshire Philos. Soc. 1849, p. 45.

† Bird's Yorkshire, tab. i. figs. 1 and 7. ‡ Brit. Mus. Petrif. p. 55.

the eminent authors of that work; but it presents in its imbricated character a greater analogy to a pine cone.

ZAMITES SUSSEXIENSIS.—At Willingdon, near Eastbourn, in Sussex, a cone nearly six inches long was discovered in a bed



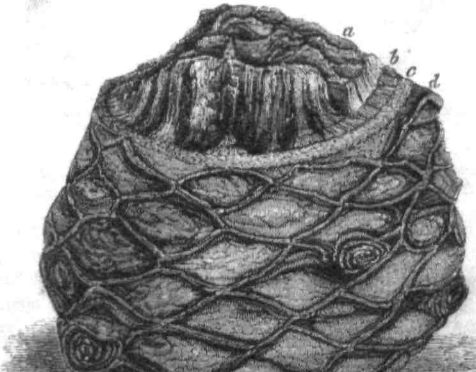
LIGN. 49. FOSSIL FRUITS OF CYCADEOUS PLANTS; ½ *nat.*
Fig. 1.—ZAMITES CRASSUS. *Wealden, Isle of Wight.*
2.—ZAMITES OVATUS. *Greensand, Kent.*

of Greensand, which abounds in fossil coniferous wood: it is of an elongated cylindrical form, and covered with hexagonal scales. I have provisionally named it *Zamites Sussexiensis* (Geol. Proc. 1843), as it presents a nearer resemblance to the fruit of Zamiæ than to that of Conifers.

TRUNKS AND STEMS OF CYCADACEÆ.—In this section I shall notice the fossil plants which occur so abundantly in the fresh-water deposits that overlie the marine oolitic limestone of the Isle of Portland, and which must be familiar to my readers, from the graphic account of the circumstances under which they occur, by Mr. Webster, and subsequently by Dr. Buckland, and Sir H. De la Beche. In my Wonders of Geology, p. 387, and Geol. Isle of Wight, p. 395, the geological phenomena of that most interesting locality,

the Isle of Portland, are so fully described, that it will not be necessary to dwell upon them; the structure and affinities of the fossil vegetables are the especial objects of our present inquiry.

MANTELLIA. *Lign.* 50, 51.—The fossil Cycadeæ of the Isle of Portland were first described botanically by Dr. Buckland, (*Geol. Trans.* vol. ii. *2d Series,*) under the name of *Cycadeoidea;* of which Memoir the account in *Bd.* p. 404, is an abstract. M. Ad. Brongniart, considering these plants as a peculiar type, referred them to a new genus, which he did me the honour to name *Mantellia* (*Prod. Veg. Foss.*). These stems



LIGN. 50. Silicified Trunk of MANTELLIA NIDIFORMIS (*Brongn.*); ½ *nat.*
(Cycadites megalophyllus. *Bd.*)
Wealden. Isle of Portland.
a. Central mass of cellular tissue. *b.* Circle of ligneous plates. *c.* Zone of cellular tissue. *d.* False-bark.

or trunks are from one to two feet in height; the circumference of the largest not exceeding three feet. The stem is

subcylindrical, and the external surface covered with the rhomboidal scars formed by the attachment of the leaf-stalks, and which are widest in their transverse diameter.

There are two species, which are readily distinguished by the form of the stems, and the difference in the size of the cicatrices left by the petioles.

The most common kind is short, and spheroidal, and the leaf-scars are relatively large; its shape has caused it to be named "*Crows' nest*," by the quarrymen, who believe these plants to be nests that were built by crows in the trees of the petrified forest with which they are imbedded. The specific name (*nidiformis*) adopted by M. Brongniart, expresses this popular notion.

Lign. 50. represents a fine example from the Portland Dirt-bed, which exhibits a structure altogether similar to that which characterizes the stems of recent cycadeous plants; namely, (*a*) a central mass of cellular tissue surrounded by circles of laminated ligneous rays or plates (*b*); then a zone of cellular tissue (*c*), and an external cylinder of false bark (*d*). The mode of increase by buds, from germs in the axillæ of the petioles, as in the living plants, is also distinctly seen.

LIGN. 51.
MANTELLIA CYLINDRICA.
(*Brongn.*); ⅙ *nat.*
(*Cycadites microphyllus. Bd.*)
Wealden. Petrified Forest of the Isle of Portland.

The other species is subcylindrical, and the leaf-scars are much smaller and more regular than in *M. nidiformis*, indicating a more delicate foliage, as expressed by Dr. Buckland's specific name: that of M. Brongniart refers to the cylindrical form of the stem. This plant was higher and more slender than its associate. Numerous buds are seen in the axillæ of the petioles in the specimen figured.

These fossils present, both externally and internally, a close relation to the bulbiform stems of the recent Cycadeæ, named *Encephalartos*, of South Africa.*

Neither the leaves nor the fruit are known: a cone found in the Dirt-bed of Portland, and attributed to these plants, appears to belong to the coniferæ of the petrified forest. Examples of Mantelliæ have been found in the quarry of Portland-stone at Swindon, Wilts.

LIGN. 52.
CLATHRARIA LYELLII.
Wealden.
A branched example of the inner axis: the original 3½ feet high.

CLATHRARIA† LYELLII. *Lign.* 52—57.—The fossil plants to which I would next direct attention were first discovered by me in the Wealden strata of Sussex, in 1820, and were figured and described under the name they still bear, in my Fossils of Tilgate Forest, in 1827. The specimens figured in that work are the most illustrative hitherto discovered, with but one exception.‡

From the imperfect state of the remains of these plants, the structure and affinities of the originals were very ambiguous, and the fossils have been placed by some eminent botanists with the Liliaceæ, and by others with the Asphodeleæ; their true botanical position is doubtless with the Cycadaceæ; for in some points they resemble the Zamiæ, in others the Cycadeæ.

* The fossil Cycads of the Isle of Portland are admirably described and illustrated in Dr. Buckland's Bridgewater Essay, (p. 497, and pl. lx. lxi.), and their internal structure is fully explained.

† Clathraria, i. e. *lattice stem*, from the scars left by the petioles.

‡ They are now in the British Museum; see Petrifactions, p. 45. *Room* I. *Case* B.

The stem of the Clathraria is composed of a solid internal axis, the surface of which is covered with reticulated fibres; the large branched specimen of this part, figured in *Lign.* 52, is the finest example hitherto obtained: it was discovered, with bones of the Iguanodon, in a *quarry* near Cuckfield, Sussex, in 1820. The axis is invested with a very thick false-bark, formed of the consolidated bases of the leaf-stalks, the insertions of which are rhomboidal and transverse. The outer surface of the bark is consequently marked with elevated lozenge-shaped cicatrices (*Lign.* 53), separated from each other by a marginal furrow, which is surrounded by a parallel ridge or band of a fibrous structure.

LIGN. 53.
CLATHRARIA LYELLII.
½ *nat.*

A stem, with rhomboidal transverse scars, left by the petioles; broken transversely and separated, to show the internal axis at *a*, which, if the pieces were united, would be received in the cavity below. The depression, or cicatrix, on the middle of the upper portion, *b*, was probably the situation of a resinous secretion, like the dragon-blood in the Dracæna.

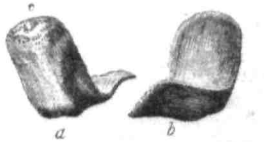
The cortical zone is generally converted into a cylinder of stone, which in some examples separates from the axis. In a beautiful specimen of this kind, *Lign.* 54, the axis projects and is surrounded by the false-bark.

The axis is solid, and has its surface strongly marked with interrupted ridges. This surface has generally patches of vascular tissue adhering to it; and there are here and there deep pits, or lacunæ, which probably contained a resinous secretion. Thin transverse sections of the axis, prepared with Canada balsam, and examined under the microscope, only give faint traces of cellular tissue.

I have spared neither trouble nor expense in endeavouring to detect the organization of this plant; numerous sections of stems have been cut, and examined microscopically, but very few exhibit any traces of structure; and in those which retain some vestiges of organization, the siliceous mass which permeates the vascular tissue, is not sufficiently transparent to yield satisfactory results. It can only be inferred that in their internal organization, as in their external characters, the Clathrariæ were most nearly allied to the Cycadeæ or Zamiæ. A remarkable specimen, (*Lign.* 56,) discovered in a stratum of Chalk-marl, near Bonchurch, confirms this view, and throws much light on the nature and relations of these vegetables.

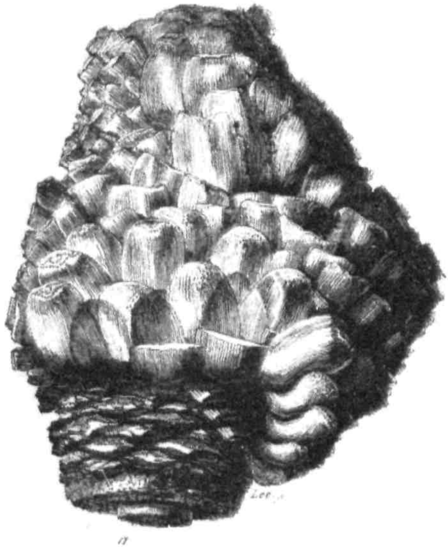
LIGN. 54.
CLATHRARIA LYELLII; ⅓ *nat.*
Wealden Sandstone. Tilgate Forest.
Portion of a stem, scored by the cicatrices of the petioles; and showing the *Axis* *a*, surrounded by the cortical cylinder.

This fossil is a portion of the summit of a stem garnished with persistent petioles, or leaf-stalks: it is fifteen inches in length, and nearly perfect at the top; and at the lower end, which has been broken off transversely, the inner axis (*Lign.* 56 *a.*), surrounded by the false bark formed by the confluence and consolidation of the bases of the petioles, is exposed. The stem has been stript of the leaf-stalks at the lowermost part, and exhibits the characteristic lattice-like scars. The petioles are for the most part entire; some of them are abortive, and others, which have supported leaves, are marked on the summits with vascular pits, indicating that the foliage



LIGN. 55.
PETIOLE OF CLATHRARIA LYELLII;
a. External aspect.
b. Inner surface.
c. Vascular pits left by the separation of the leaf.

was shed naturally; as shown in *Lign.* 55 *a.* These petioles were probably persistent for some years, as in the existing



LIGN. 56. CLATHRARIA LYELLII; ½ *nat.*

Chalk-marl. Bonchurch, Isle of Wight.

The summit of a stem garnished with petioles; the lower part shows the cicatrices left by the removal of some of the petioles: *a*, the internal axis.

Cycads. The opposite side of the stem to that represented is covered with elongated and flattened petioles.

On the sea-shore bounded by cliffs of Wealden rocks, in the Isle of Wight, water-worn portions of stems of Clathrariæ are occasionally met with; and these are impressed with the lozenge-shaped areas left by the petioles, as in the specimen, *Lign.* 57. Mr. Saxby, of Bonchurch, has favoured

me with the loan of a thin section of a stem of Clathraria, in which the bundles of vascular tissue in the petioles appear to be made up of spiral vessels. From what has been advanced, it is obvious that these remarkable plants of the Wealden flora were gymnosperms, closely related to the Cycadeæ.

LIGN. 57.
CLATHRARIA LYELLII; ½ *nat.*
Specimen, showing the water-worn external surface.

Vestiges of roots, seed-vessels, and panicles, have been found in the Wealden, which may possibly belong to the Clathraria; but the evidence as to their presumed relationship is at present too vague to require further notice.

ENDOGENITES EROSA.—(*Geol. S. E.* pl. i.; *Tilg. Foss.* pl. iii.; and by Dr. Fitton in *Geol. Trans.* vol. iv.).—The genus *Endogenites* was established by M. Ad. Brongniart for the reception of those fossil stems and woods, whose internal structure is endogenous, but which are too imperfect to be referred to any particular family. In this category must be placed certain silicified stems having a carbonaceous cortical investment, which I discovered in the strata of Tilgate Forest, in 1820.

These fossils often occur in the layers of lignite which traverse the clay-beds in some parts of the Weald of Sussex. They are from one to eight inches in diameter, and five or six feet in length, and of very irregular shapes; I have not observed any indications of branches. Some specimens are subcylindrical in the middle, and gradually taper to a point at each end; others are of a depressed clavated form, like some of the Cacteæ or Euphorbiaceæ. They are generally silici-

fied, and, when in situ, are invested with a friable carbonaceous crust, of a glossy lustre, which soon falls to pieces on exposure to the atmosphere, so that cabinet specimens seldom retain any vestiges of it. When this coaly matter is removed, the surface of the silicified stem is seen to be traversed by numerous fine meandering grooves, and deep, tortuous channels, disposed in an irregular manner, in a longitudinal direction. These channels or vessels, which are generally lined with quartz crystals, give the surface that eroded appearace which suggested the specific name, *erosa;* but this term is inapplicable, for the perforations and sinuosities are not the effect of erosion, but result from the structure of the original. Polished sections, seen by transmitted light, are represented in Dr. Fitton's memoir (*Geol. Trans.* vol. iv.); and I have had many slices ground as thin as possible, in the hope of detecting the characters of the vascular tissue. In one example there are indications of a cycadeous structure, which favour the conclusion, that the originals belonged to an extinct tribe of gymnosperms; but in other specimens, bundles of vascular tissue, resembling those of palms, are apparent.

Large water-worn stems of *Endogenites* are occasionally washed out of the Wealden cliffs at Hastings, and in Sandown and Brook Bays, in the Isle of Wight.

FOSSIL CONIFERÆ.

The other great natural order of Gymnospermous phanerogamiæ,* the *Coniferæ,* or cone-bearing—so named from the form of their fruit, of which the fir-cones and larch-juli are familiar examples,—comprise the extensive tribes of Firs and Pines, and the Cypresses, Yews, Junipers, Cedars, &c., among which are the loftiest trees on the face of the globe.

* Signifying, *flowering plants with naked seeds.*

The Conifers are all arborescent, having numerous branches, which are in general disposed with much regularity. The leaves are commonly acicular or needle-shaped, narrow, and linear: in two or three genera, however, (*Dammara, Podocarpus*,) the foliage departs remarkably from the ordinary type, the leaves being broad and flat. The structure of the stem, though in its general characters essentially exogenous (see *Plate IV. fig.* 4),—that is, having a central pith, medullary rays, zones of vascular tissue, and concentric circles of growth, —differs in the almost entire absence of spiral vessels, and in the peculiar modification of the radiating bands of woody fibre, which are made up of uniform longitudinal vessels, and run parallel with the medullary rays. The lateral walls of these vessels have longitudinal rows of areolæ, which are generally circular or elliptical, but when in contact are angular and polygonal: each areola has a small pore or punctation in the centre. These discs, glands, or ducts, as they are called, are variously arranged in different genera; they are generally confined to the contiguous and corresponding lateral surfaces of the fibres; and occur rarely, if ever, on the inner and outer aspects of the vessels. In the recent genus Pinus the rows of ducts are single in some species; in others both single and double series occur, but never more than two, and in the latter case the ducts are always parallel to each other (see pl. v. 3*b. Wond.* pp. 696, 725). But in the *Araucariæ*, or Norfolk Island Pines, the vessels have double, triple, and sometimes quadruple, rows of discs, of smaller size than in the common pines; and in the double series, these bodies are always arranged alternately (*Wond.* p. 696. *Bd.* 56 *a.*); Mr. Nicol states that there are about 50 discs in the length of $\frac{1}{20}$ inch, the diameter of each not exceeding $\frac{1}{1000}$ inch.

The form and arrangement of these ducts, and the structure of the medullary rays, are the characters on which the scientific botanist relies for the detection of the affinities of

the coniferous trees, whose mineralized trunks and branches, in a fragmentary state, are, for the most part, the only relics of these important tribes of the lost floras of the earlier ages of our planet.*

The great value of these data will be shown in the sequel.

The stems, fruit, and foliage, of Coniferæ, occur in the various fossiliferous deposits, from those containing the earliest traces of terrestrial vegetation to the newest tertiary strata; and a large proportion of the petrified wood found in the British formations belongs to trees of this order. The presence of rows of ducts on the ligneous fibres, which is peculiar to this division of gymnosperms, as we have already explained (*ante*, p. 58), is so easily detected by microscopic examination, that the merest fragment of fossil coniferous wood retaining internal structure, may without difficulty be recognized. The number of rows, and the opposite or alternate arrangement of the areolæ, are characters which, in the living pines and firs, enable us to refer the respective trees to European or exotic forms; but in the fossil coniferous wood, much diversity exists in other not less important points of structure, and for the successful cultivation of this department of fossil botany, works especially devoted to the subject must be consulted. To the English student, Mr. Witham's beautiful volume, "Observations on the Structure of Fossil Vegetables, Edinburgh, 1831," will be found a valuable guide.

* I know not a more delightful and instructive branch of science for the young and inquiring of both sexes, than this department of Fossil Botany, which the recent improvements in the microscope have rendered so accessible; and yet there are but few cultivators of fossil botany in England!

Fossil Coniferous Wood.—The coniferous wood of the secondary formations of England, belongs for the most part to the Araucarian type: that is, the glands, when in double rows, are placed alternately, as in the Norfolk Island Pines (*Wond.* p. 696), and not side by side, as in the common European species of firs and pines (*Bd.* p. 486). Numerous sections of this kind of fossil wood are figured by Mr. Witham, from specimens obtained from Lennel Braes, on the banks of the Tweed, near Coldstream; and from near Allanbank Mill, in Berwickshire (*Obs. Foss. Veg.* p. 14); a fossil trunk, 40 feet long, discovered in Craigleith Quarry, near Edinburgh, at a depth of 136 feet, possessed the same structure.

Palæoxylon (*coniferous wood of the Coal Measures*).—The existence of coniferous trees in the Carboniferous flora, and the fact that their trunks and branches had contributed to the formation of coal, was first discovered and clearly demonstrated by Mr. Witham in the work to which reference has been made. Figures of the peculiar structure observable in thin slices of coal, are given in *Obs. Foss. Veg.* pl. iii. iv. v. This carbonized wood resembles that of the Araucariæ in the multiple series of ducts, and their alternate arrangement; but the presence of thick compound medullary rays in these stems,—a character unknown in any living conifers,—led M. Brongniart to place them in a separate genus—*Palæoxylon* (ancient wood); characterized by the presence of medullary rays formed of numerous layers of cells, which are not arranged in superimposed series, and that present a lanceolate or oval form, in a section perpendicular to their direction.*

* The *Pinites Withami*, and *P. medullaris*, of Lindley and Hutton, figured in Mr. Witham's work, belong to this genus. It may interest the reader to know that slices of these woods prepared for the microscope by Mr. Nicol, (presented to me by the late Dr. Henry, of Manchester,) not only expose the vegetable organization in an

nearly related to the fruit of Araucaria excelsa, was discovered in the Dirt-bed.

At Brook-Point, in the Isle of Wight, an equally interesting fact may be observed. At the base of the cliff, which is entirely composed of Wealden clays, shales, and sandstones, there is a vast accumulation of petrified firs and pines, imbedded in the indurated grit that forms the lowermost strata on the sea-shore, and of which the reefs and rocks, produced by the encroachments of the sea, and that extend far from land, are composed. These can be examined at low-water, and the observer, upon lifting up the fuci and algæ which cover them, will find the rocks and masses of stone to consist of petrified trunks of coniferæ. There are no erect trees as in Portland; on the contrary, the stems are prostrate, and lie confusedly intermingled, and associated with bones of Iguanodons and other reptiles, and large mussel shells; the whole presenting the characters of a raft of forest trees which had drifted down the stream of a vast river, and entangled in its course the limbs and carcasses of animals that were floating in the water, and the shells that inhabited the river, and at length became submerged in the bed of the delta or estuary. Both foliage and fruit have been found in the Wealden deposits at Brook, and will be described hereafter.*

In the sands of the Desert of Sahara, in Egypt,—among the mammalian bones of the Sub-Himalayas,—and in the tertiary deposits of Virginia associated with cycads,—drifted trunks of conifers have been discovered.

Fossil trees of this family also occur in various localities in Australia and Van Diemen's Land, the wood of which is in some parts calcified, and in others silicified. The same trunk often has externally a white friable calcareous zone, several inches thick, traversed by veins of silex, or opaline chalcedony, while the centre is a silicified mass; in

* See Geol. I. of Wight, chap. x. and xi.

both states the internal structure may be detected. This kind of fossil wood is to be seen in most cabinets, a large quantity having been sent to England by emigrants.* These fossil trees appear to have been subjected to the same mutations as those of the Isle of Portland, for they are described as standing erect to the height of several feet in a bed of arid sand, apparently in the places where they grew; their petrified branches being scattered around them. They so entirely preserve their natural appearance, that one of the colonists mentions among the extraordinary sights he witnessed on his first arrival in New Holland, the burning of trees into lime to manure the ground.

A fossil pine forest, on the eastern coast of Australia, in the inlet called Lake Macquarrie, is described by the Rev. B. Clarke, as occurring at the base of a mountain range, composed of conglomerate and sandstone, with subordinate beds of lignite; an alluvial plain extends to the water's edge, covering the sandstone rock which is seen in situ beneath. Throughout this plain, stumps of fossil trees project from the ground, and present the appearance of a forest in which the trees have all been broken off at the same level.* At the distance of some yards from the shore, a reef is formed by vertical rows of the petrified stems, which project out of the water. Many of the fossil stems on the strand have the remains of roots extending into the sandstone below the alluvial deposit, and, like those in the Island of Portland, are in some instances surrounded by an accumulation of rock, which forms a mound of a higher level than the surface of the stratum. The trunks are, generally, three or four feet high, and from two to six feet in diameter. The wood is silicified, and veins of chalcedony traverse its substance between the concentric rings and medullary rays; in several examples, from 60 to 120 annual circles of growth

* My late friend, Sir Francis Chantrey, had a magnificent specimen, which is now in the British Museum. See Petrifactions, p. 59.

were observable. Beds of lignite occur in the neighbouring hills, both above and below the fossil trees; many localities along the eastern coast of Australia are mentioned, as presenting similar phenomena. I may add that the only fragment of petrified wood found by Mr. Walter Mantell in New Zealand is coniferous.

In the valley of the Derwent, in Australia, opalized coniferous trees of a similar character were observed under very extraordinary circumstances, by the distinguished traveller, Count Strzelecki. Truncated stems were found standing erect in a bed of scoriaceous basalt (lava) and trachytic conglomerate: but in some instances only basaltic casts of the trunks remain. This curious phenomenon can only be explained by supposing the silicified stems to have resisted the intense heat of the incandescent lava, while trees placed in circumstances unfavourable to their petrifaction were consumed: but the latter, being either saturated with water, or fresh and green, were burnt slowly, and left cylindrical moulds in the cooled basaltic scoriæ, with impressions of the external surface of the bark; these moulds were filled up by a subsequent eruption, and thus basaltic casts of the consumed trees were formed.*

CONIFEROUS WOOD IN OXFORD CLAY.—It would occupy too much space to notice the numerous localities in which fossil remains of conifers occur in the Liassic and Oolitic formations of England.

In the Oxford and Kimmeridge Clays waterworn trunks and branches of large pine-trees are often met with. An interesting deposit of these remains was brought to light by my youngest son (Mr. Reginald Mantell), when constructing the branch line of railway from the Great Western to Trowbridge, in Wilts. In the progress of the work, extensive sections were cut through the Oxford Clay, and laid bare a large quantity of drifted wood, much of which was not

* Physical Description of New South Wales, by Count Strzelecki.

petrified, but in the state of bog-wood, and was used for fuel by the workmen. Trunks ten or twelve feet long were met with, to which serpulæ, oysters (*Ostrea delta*), and other shells were adherent. These vegetable remains were associated with Belemnites, Belemnoteuthides, Ammonites, &c.; and had evidently been drifted far out to sea by currents.*

Coniferous Wood in the Chalk formation.—The arenaceous limestones of the Greensand of Kent and Sussex abound, in some localities, in water-worn masses of coniferous wood, which are often perforated by boring mollusks, as *Teredo, Fistulana, Gastrochæna,* &c. In the Iguanodon quarry of Kentish rag, near Maidstone, large quantities of these remains occur, and Mr. Bensted has collected several cones belonging to different kinds of conifers; one of these appears to be a species of *Abies*, or Fir:† it was associated with fragments of trunks and branches, whose internal structure proved their relation to the fruit. *Plate V. fig.* 2, are microscopic views of transverse and longitudinal sections of this wood; 2^a shows the cellular tissue in a transverse slice, seen by reflected light; 2^b a vertical section in the direction of the medullary rays, exhibiting the vessels studded with single rows of glands. This wood occurs both in a calcareous and siliceous state; in some examples the external zones are calcareous, and the inner siliceous; in others the entire branch is changed into black flint, in which the coniferous structure is beautifully preserved.

Near Willingdon, in Sussex (*Geol. S. E.* p. 172), a bed of sand, immediately beneath the Galt, contains a layer of water-worn fragments of stems and branches, of small size; they are generally perforated by *Gastrochænæ*, and the cavities formed by these depredators are filled with particles of green chlorite sand. The structure of this wood is repre-

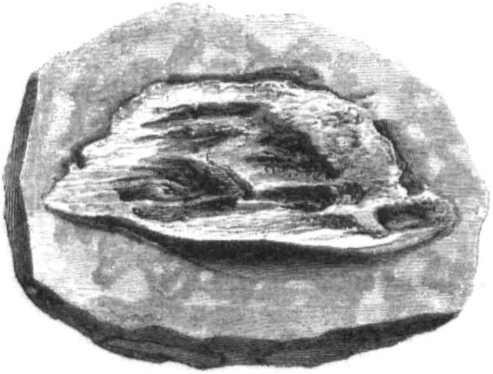
* See Wond. p. 502. Geol. Journal, vol. vi. p. 311.

† It is figured and described as *Abies Benstedi*, by the Author. Geol. Proc. January, 1843.

sented in *Plate V. fig.* 3^a a transverse, and 3^b a vertical section, viewed by reflected light; in 3^b the vessels are dotted with two parallel longitudinal rows of very minute glands, arranged alternately, as in the Araucariæ; a fragment of one of the medullary rays is seen near the middle of the specimen.

In this deposit of coniferous wood, two or more fruits apparently referable to *Zamiæ* have been discovered; one specimen, five and a half inches long, and of an elongated cylindrical form, covered with rhomboidal eminences, I have figured and described as *Zamites Sussexiensis.**

The White Chalk of England has afforded but few traces of plants of this family. Fragments of coniferous wood are,



LIGN. 58. FRAGMENT OF CONIFEROUS WOOD IN FLINT.
From a wall in Lewes Priory.

however, occasionally found in the state of carbonaceous, or reddish brown friable masses, and when this substance is removed, the surface of the chalk is seen to be marked with impressions of ligneous fibres; sometimes the surface is

* Geol. Proc. 1843.

studded over with little pyriform eminences, which are cretaceous casts of perforations made by insects in the wood. These specimens, when all traces of the wood are absent, are very puzzling to those who are not aware of their origin.

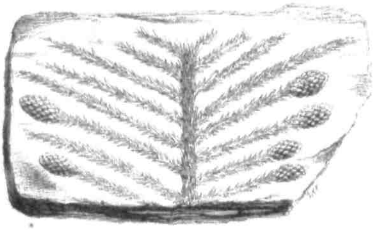
Occasionally silicified fragments of wood are found imbedded in flint. I have an interesting specimen of this kind obtained from a wall in Lewes Priory (*Lign.* 58), and though it must have been exposed to the influence of the weather for nearly eight centuries, its surface still exhibits coniferous structure.

TERTIARY CONIFEROUS WOOD.—The Tertiary formations in some localities abound in coniferous plants and trees, which, in the Paris basin, are associated with bones of mammalia; several species of pine (*Pinus*) and of yew (*Taxus*) from those deposits are described by M. Brongniart. I have collected fossils of this kind from the London Clay of the Isle of Sheppey, Bracklesham Bay, and Bognor in Sussex, and Alum Bay, in the Isle of Wight; and from the plastic clay at Newhaven.

FOSSIL FOLIAGE AND FRUIT OF CONIFERÆ.—From this digression on the pine-forests and drift-wood of the secondary formations, we return to the examination of the foliage and fruits of this order of vegetables that are preserved in the mineral kingdom.

ARAUCARIA PEREGRINA (*Lindley and Hutton*). *Lign.* 59, *fig.* 1.—With the trunks and branches of conifers of the Lias, cones and foliage are occasionally found: a beautiful example of a branch with the leaves preserved, is figured, *Lign.* 59. This fossil has been so admirably cleared from the shale which invested it (by Miss Philpot) that even the surface of the leaves is exposed. It so closely resembles a twig of *Altingia excelsa*, that the eminent authors of Foss. Flor. have named it as above. But M. Brongniart states that the foliage differs from that of the two living groups of Araucariæ: in *Araucaria Brasiliensis*, the leaves

branches, resembling those of Araucaria excelsa, and which are thickly beset with foliage. The leaves are sessile, compact, enlarged at the base, tetragonal or falciform, and slightly decurrent; they often vary considerably in form and length on the same bough. The branches are in some



LIGN. 60. WALCHIA HYPNOIDES; $\frac{1}{3}$ *nat.*
Permian, Lodève.
Part of a bough with six of the branches bearing terminal cones.

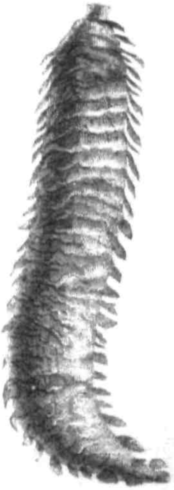
examples terminated by oblong cones, composed of imbricated, oval or lanceolate, pointed scales, the summits of which are not recurved, as in the Araucariæ. The trees of this genus are closely related to the *Araucaria excelsa*, and *A. Cunninghami*. Some species occur in the Coal formation at St. Etienne and Autun;* others (as *Walchia hypnoides*) in the schists of Lodève, and in the copper slates of the Zechstein in Mansfeld.†

ABIETITES.—To the Abies, or Fir, several cones found in the Wealden deposits of Sussex and Hants closely approximate in the form and structure of their scales. The most remarkable is the very elongated coniferous fruit, first discovered by me in the Wealden at Brook Point, and described and figured in my Geology of the Isle of Wight (*2d edit.* p. 452), under the name of *Abietites Dunkeri*, in honour of

* "Mines de Houille de Vettin, &c." See "Tableau des Vég. Foss." p. 70, par M. Brongniart.

the eminent geologist who has so successfully and diligently explored the Wealden of the North of Germany.

I have been so fortunate as to collect from thirty to forty specimens of these fruits of the conifers of the country of the Iguanodon, associated with trunks and branches, and imperfect vestiges of single lanceolate leaves.



Lign. 61.
Abietites Dunkeri.
Wealden; Isle of Wight; ⅓ nat.
Fir-cone, showing the imbricated scales, and many of the bracteæ.

Abietites Dunkeri. *Lign.* 61.—These cones are of a cylindrical form, and greatly elongated: the largest specimen is thirteen inches in length, and but three inches in circumference. The scales are broad, slightly convex without and concave within, obovate or subrotund, with a prominent midrib, edges thin and entire. Leaves solitary, slender, slightly curved, from 1 inch to $1\frac{1}{2}$ inch in length. The cones were garnished with bracteæ, which are seen on the margins *of the fossil when imbedded in the rock.* Whether the foliage that forms the constituent substance of a large proportion of the bituminous coal of Hanover (*ante*, p. 74), and which has been figured and named by Dr. Dunker *Abietites Linkii*, belongs to the same species of Fir as these cones, I am unable to determine. The seeds are of an ovate form: the pericarp is in the state of carbon, and filled or lined with pyrites or calc-spar.

These cones are generally found more or less pyritified, and are extremely beautiful objects when first collected; but like the fruits from the Isle of Sheppey, similarly mineralized, often decompose, in spite of every precaution, after exposure to the air but for a few weeks.

A small sub-ovate fir-cone found with coniferous wood in

the Kentish-rag of Mr. Bensted's quarry, near Maidstone, (*ante*, p. 173), and figured and described by me as *Abies Benstedi*, probably belongs to the coniferæ of the Wealden, since it was associated with drifted bones of the Iguanodon.

FOSSIL CYPRESSES.—The tribe of conifers called *Cupressus* or Cypress, (distinguished from the firs and pines by the leaves being mere scales, and the cones consisting of small wooded peltate bracteæ, and by other botanical characters,) including the Juniper and Arbor-vitæ, appears to have flourished during the whole of the secondary epochs; for fossil leaves and stems referable to this family, but whose generic affinities cannot be determined with precision, have been found in the Trias, Lias, Oolite, and Wealden deposits.

LIGN. 62.
THUITES KURRIANUS; *nat.*
Wealden. Hastings.

THUITES KURRIANUS. *Lign.* 62.—The *Thuja* or Arbor-vitæ, a plant too well known to require description, is the type of the fossil plants distinguished by the name of *Thuites*. Many years since I discovered vestiges of branches and leaves of some species of this genus, in the ironstone of the Wealden beds, at Heathfield in Sussex (*Geol. S. E.* p. 228); and of late, many specimens have been found in strata of the same formation in England and Germany. The branch here figured, from the cabinet of S. H. Beckles, Esq. will serve to illustrate the appearance of these fossil plants. Some small fruits found in the ironstone of Heathfield may possibly belong to Cypresses. The foliage and fruit of five or six distinct species of Thuites have been discovered in Tertiary strata.

VOLTZIA.* (*Wond.* p. 547).—This extinct genus of plants

* Named in honour of the late M. Voltz, of Strasburg, by whom they were first discovered. The specimens in the British Museum, from my collection, were presented to me by M. Voltz.

is peculiar to the Trias (*Grès bigarré*) or New Red deposits, and is one of the most characteristic of the fossil coniferæ. The specimens first found were from *Sultz-les-Bains*, near Strasburg. The leaves are alternate, arranged spirally, sessile, and decurrent, and have much analogy with those of certain Araucariæ. The fruits are oblong cones, with cuneiform scales, slightly imbricated, not contiguous, and generally with from three to five lobes.

TAXITES.—*Some branches found in the Stonesfield slate*, and bearing a general resemblance to twigs of Yew (*Taxus*), are described under the above name, but their analogies are doubtful. (See *ante*, p. 145.)

NŒGGERATHIA.*—I must briefly notice the coal-plants which M. Brongniart has placed under this genus, because the foliage of some species appears to have entered largely into the formation of certain seams of coal, although the perfect form of the leaves is unknown. The foliage referred to *Nœggerathia* consist of pinnated, or deeply pinnatifid, simple leaves. These leaves, or leaflets, are either elongated, linear, lanceolate, wedge-shaped or flabelliform, and entire, or deeply lobed at their extremity, and are traversed by numerous, fine, equal nerves, slightly diverging from the base, but almost parallel. The affinities of these plants are not satisfactorily made out: M. Brongniart considers them to approach nearest to the Cycads or Conifers; perhaps forming a connecting tribe between those two great groups of gymnosperms.†

FOSSIL RESINS.—AMBER.—The resinous secretions of Conifers are occasionally found in a fossil state. When the tunnel was carried through Highgate Hill, in 1811, concretionary lumps of a brittle substance were discovered, which proved, upon analysis, to be the resin of a coniferous tree

* A leaf of *N. flabellata* is figured in Foss. Flor.

† Tab. Veg. Foss. p. 64.

changed by mineralization. In a bed of fossil wood, near Hythe, in Kent, a resin was found that partook of the properties of amber and retinasphalt; it was of a clear red colour, very infusible, and acted upon with difficulty by many chemical solvents.*

The pollen of pines or firs occurs in a tertiary deposit at Egra, in Bohemia; this bed is entirely composed of pollen and the frustules of many kinds of diatomaceæ.†

Amber, so remarkable for its electrical properties, and so largely used for ornamental purposes, is a fossil resin, the product of an extinct species of pine (*Pinus succinifer*), which, though nearly allied to *Pinus abies*, and *P. picea*, is essentially distinct. The Amber in the European markets is principally collected from the shores of the Baltic, between Memel and Konigsberg, being washed out of submerged beds of lignite, and thrown up on the strand by the waves. Amber is occasionally found on the eastern and northern shores of England. The forests of Amber-pines appear to have been situated in the south-eastern part of what is now the bed of the Baltic, in about 55° north latitude, and 37° to 38° east longitude, and were probably destroyed at the commencement of the Drift period.

Insects, spiders, small crustaceans, leaves, and fragments of vegetable tissue, are often imbedded in amber; and a few hairs and feathers of mammalia and birds have been detected. These organic bodies must have become immersed in this substance when it exuded from the trees in a viscid state, for they are often preserved as fresh and beautiful as if recently embalmed in the liquid resin. Upwards of 800 species of insects have been discovered, chiefly referable to Aptera, Diptera, Neuroptera, Coleoptera, Libellula, &c.: by far the greater number belong to extinct forms.

The vegetable remains comprise four species of pine, and

* Geological Proceedings, 1843. † Described by M. Ehrenberg.

species of cedar, cypress, juniper, yew; and of oak, poplar, beech, ash, &c.; and a few ferns, mosses, liverworts, confervæ, and fungi. The Amber appears to have exuded from the bark and wood, but chiefly from the root-stock, as is the case with the *Copal* and *Animé*, which are resinous substances obtained from certain trees in India and America, and largely employed for varnish: these resins are often substituted for true amber, especially when they contain insects, &c.; but the latter are always of the existing indigenous species of the country. The difference observable in the colour of the various species of amber, is attributable to accidental chemical admixtures.*

FOSSIL PALMS (*Palmacites*).—Reserving an account of the fossil plants belonging to the other grand division of *Dicotyledons*, the *Angiosperms* (*ante*, p. 61), for the last section of the present chapter, I proceed to notice the most important family of the *Endogens*, or *Monocotyledons*, whose remains occur abundantly in many tertiary deposits—the PALMS.

The Palms are, for the most part, lofty trees, having a single cylindrical stem, which, like that of the arborescent ferns, rises to a great height, and is crowned with a canopy of foliage. The trunks are solid, most dense on the outer part, and in some species (as the Cane-palms) are coated with a thin siliceous epidermis. At a little distance above the surface of the ground, strong, simple, rope-like roots are sent off from the stem, appearing like clusters of stays or braces to support the trunk; and the base of the petrified palm-trees often exhibits vestiges of these organs.† The leaves are supported by petioles, and are in most species very large;‡ they are either pinnated or flabellated (fan-shaped), and sometimes nearly split in half: the veins or nervures

* Petrifactions, p. 23.

† Specimens in the Brit. Mus. Petrifactions, p. 12.

‡ In the Fan-palm (*Corypha*), the leaf is sometimes twenty feet broad.

are parallel, and the interspaces plaited like the folds of a fan. The surface of the stem is scored by transverse scars formed by the separation of the petioles, and these markings assist in the identification of the fossil trunks of palm-trees. The fruit is in some kinds a single drupe, as the Cocoa-nut; in others a cluster of soft pericarps, as the Date.

The Palm family is divided into upwards of sixty genera, comprising more than a thousand species: the greater number are inhabitants of tropical countries. Stems, with the external surface and internal structure preserved, and the foliage, and fruit, of several kinds of Palms, have been found in a fossil state, and chiefly in the Tertiary formations. Examples of the large silicified palm-stems from the West India Islands, where they occur imbedded with corals petrified in the same manner, are to be seen in the British Museum,* and most public collections: and sliced polished sections, exhibiting the monocotyledonous structure, are common in private cabinets. The endogenous organization of the stems is so obvious as to leave no doubt as to the class to which the trees belong, but M. Brongniart states, that, in the absence of the foliage and fruit, it is seldom possible to pronounce with certainty that a fossil monocotyledonous stem belongs to a Palm; for the internal structure alone does not enable the botanist to fix upon any characters which will distinguish the stems of Palms from those of Pandanus, Agave, Yucca, Aloes, Dracæna, &c. Fossil monocotyledons known by their stems only, are therefore arranged by M. Brongniart under the general name of *Endogenites.*

The *Palmacites carbonigenus* of Corda, and other supposed palm-trees of the Coal formation, are regarded by the same eminent botanist as essentially differing in structure from this family, and belonging to an extinct tribe of exogens.

That a large proportion of the exogenous stems found in

* Petrifactions, p. 52.

the Tertiary deposits are true palms, there can, however, be no doubt, for the foliage and fruit, which are occasionally associated with them, confirm the inference drawn from the characters of the trunks.

Stems, leaves, and fruits of Palms have been discovered in the Paris basin, by M. Ad. Brongniart (*Bd.* pl. lxiv. p. 515); and silicified trunks in many other places on the Continent; but no fossils of this kind surpass in beauty and interest those which are found in the West Indies. A slice of a silicified stem from Antigua is represented, as seen by reflected light, in *Plate V. fig.* 1; it admirably displays bundles of vessels imbedded in cellular tissue.

Silicified stems of monocotyledons, related to the Palms, are very widely distributed, and have been collected among mammalian remains in Ava, and in the Sub-Himalaya mountains.

FOSSIL PALM-LEAVES.—The pinnated and fan-shaped leaves of the Palms are so peculiar as to be easily recognized in a fossil state. Though many specimens have been found in the tertiary strata of the Continent, but two or three examples have been met with in England. The first discovered British specimen is in my cabinet, and was obtained by Mr. Fowlstone, of Ryde, from the fresh-water limestone of Whitecliff Bay, in the Isle of Wight. It is thirteen inches in length, and eleven in width: fresh-water shells and plants are imbedded with it. It is figured in Geol. I. of Wight, *2d edit.* p. 431. This species (*Palmacites Lamanonis*) occurs also at Aix in Provence, in great perfection, associated with Insects, Fishes, fresh-water shells, &c. (*Wond.* p. 260. *Petrif.* p. 52).

Twelve species of palm-leaves are enumerated by M. Unger, from the Tertiary deposits of the Continent. One species has been found in the Chalk formation of Silesia; the most ancient strata in which the remains of undoubted palms have as yet been observed.

The fossil palm-leaves of the pinnated form are named *Phœnicites*,* and examples occur in the Tertiary grits of Puy en Velais. I am not aware that leaves of this type have been found in England: diligent research in our tertiary leaf-beds (at Whitecliff Bay, Alum Bay, Bournemouth, Wareham) will probably sooner or later discover them. The leaflets have a well-marked median nerve, with fine nervures running parallel with it; a character by which the foliage of *Phœnicites* may be distinguished from that of the Cycadeæ.

FOSSIL FRUITS OF PALMS.—Although certain fruits found in the coal measures have been referred to the palm-tribe by M. Unger, Dr. Lindley, and other botanists, M. Brongniart is of opinion that no such identification can be established; the same remark applies to the Carpolithes from the Oolite; in fine, the Tertiary deposits have alone yielded fruits that can be unquestionably referred to plants of this order. The most productive British locality of fossil fruits of Palms, and of many other vegetables, is the Island of Sheppey; and I purpose describing in this place, not only the remains of this family, but also of the other plants associated with them.

FOSSIL FRUITS OF THE ISLE OF SHEPPEY. — This little island, which is situated in the mouth of the Thames, is entirely composed of the London Clay, with bands of septaria. On the north, there is a range of cliffs, about two hundred feet high, which is being continually undermined by the waves, and large masses of the clay are thrown down, and innumerable fruits, seeds, branches and stems of trees, and other fossils, are exposed on the strand at low water. The vegetables are strongly impregnated with iron pyrites, and as this mineral speedily decomposes when exposed to the atmosphere, the choicest examples often fall to pieces,

* From *Phœnix dactylifera*: the Date-Palm.

even when preserved in the cabinet.* The nodular masses of indurated clay, termed septaria, contain the best preserved and most durable fossils. The fossil fruits, or carpolithes, occur in such profusion, that a large collection can easily be made; they comprise several hundred species, few of which have been scientifically investigated.†

Mr. Parkinson has given admirable figures of several of the Sheppey fruits, particularly of the large palm-like nuts, called "*petrified figs*." (*Org. Rem.* vol. i. pl. vi. vii. *Pict. Atlas*, pl. vi. vii.) M. Ad. Brongniart has named several in his *Prodrome*; but without figures the descriptions are useless to the student. Mr. Bowerbank has published two numbers of a work entitled, "*History of the Fossil Fruits of the London Clay*," with seventeen plates; from which I have selected a few subjects for illustration. The fruits described are the following:

1. Fruits having a downy structure, like the Cotton plant.

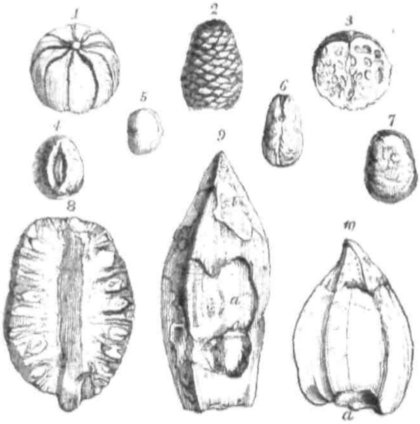
2. *Cucumites.* Seeds of plants of the cucumber family. *Lign.* 63, *fig.* 1 and 3. These fossil fruits so closely resemble the seeds of various members of the recent genus *Cucumis*, or Cucumber, comprising the Gourd, Water-melon, &c., both in outward form and internal structure, that there is no reasonable doubt of their belonging to plants of the same family; hence the name *Cucumites* or fossil cucumbers.

3. Cones of a tree allied to the genus *Petrophila*, of New Holland. *Lign.* 63, *fig.* 2 and 8.

* Mr. Bowerbank, who possesses an unrivalled collection of these fruits, keeps them in stopper-bottles filled with water, placing the different species separately, and labelling the phials. I have successfully employed mastic varnish, first wiping the specimens dry, and removing any saline efflorescence by means of raw cotton, and then brushing in the varnish with a stiff hair-pencil.

† See vol. ii, Excursion to the Isle of Sheppey.

4. Seeds of the Bean family, some of which resemble those of the common Scarlet-runner. *Lign.* 63, *fig.* 5, 6, 7.



LIGN. 63. FOSSIL FRUITS FROM THE ISLE OF SHEPPEY.

London Clay.

Fig. 1 and 3.—*Cucumites variabilis*: fig. 3, is a vertical section, showing the seeds. *Lign.* 64, fig. 6—½ *nat.*

2 and 8.—*Petrophiloides Richardsoni*: ⅓ *nat.* Fig. 8, is a vertical section, showing the disposition of the seeds in the cells formed by the confluent scales—½ *nat.*

4.—*Wetherellia variabilis*: a section of the fruit, in which state it is called coffee-berry by the collectors—⅓ *nat.*

5 and 6.—*Faboidea semicurvilinearis*: fig. 5, side view—¼ *nat.*

6.—Is the face of a similar seed—⅓ *nat.*

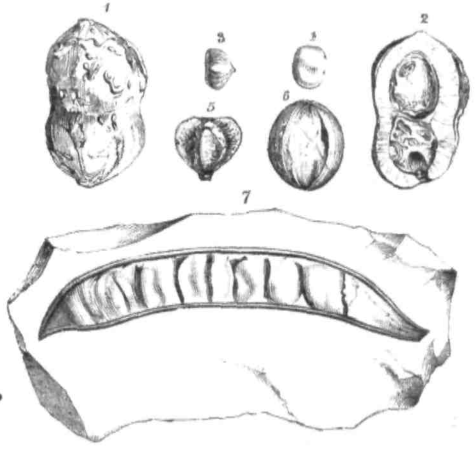
7.—*Faboidea bifalcis*: side view—⅓ *nat.*

9.—*Nipadites lanceolatus*: *a*, the seed; *b*, the shell, or pericarp—½ *nat.*

10.—*Nipadites cordiformis*: *a*, the extremity of the seed, imbedded in the shell—⅓ *nat.*

5. *Wetherellia*; pulpy fruits divided into two lobes by the expansion of the ripe seeds. As the section thus exposed bears some resemblance to a coffee-berry, these fossils are popularly called petrified coffee-berries. This genus has no known living representative. *Lign.* 63, *fig.* 4.

6. Fruits allied to the Palm tribe. (*Nipadites*). *Lign.* 63, *fig.* 9, and 10.
7. Fruits of leguminous plants, differing from any known recent. *Lign.* 64, *fig.* 1, 2, 3, 4.
8. Seeds, allied to the *Amomum*, or Cardamom tribe. *Lign.* 64, *fig.* 5.



LIGN. 64. FOSSIL FRUITS FROM THE ISLE OF SHEPPEY. *London Clay.*

Fig. 1 and 2.—*Zulinosprionites latus.* 2. A section, showing the receptacles for two seeds.—⅔ *nat.*
3.—*Leguminosites dimidiatus*; side view.—½ *nat.*
4.—*Leguminosites subquadrangularis*; side view.—½ *nat.*
5.—*Cupanoides lobatus* —½ *nat.*
6.—*Cucumites variabilis.*—½ *nat.*
7.—*Mimosites Browniana*; from Ossington, Suffolk. A seed-pod of an *Acacia*, or other plant of the *Mimosa* family.—⅔ *nat.*

9. Seeds of *Cupressinites*, or plants related to the Cypress.
10. Seeds resembling those of the *Laburnum*.
11. Seed-pod of a species of *Acacia*, or *Mimosa*. *Lign.* 64, *fig.* 7.—⅔ *nat.*

NIPADITES. *Lign.* 63. (*Pict. Atlas*, pl. vi. vii.) — The most remarkable fruits in the above catalogue are those which, from their appearance when compressed, are known to collectors by the name of "*petrified figs*" (*Lign.* 63, *fig.* 9, 10). Some specimens attain a considerable size, and are from five to seven inches long. The nut, and the pericarp or shell, are often well preserved. These fossils were referred to the *Cocos* by Mr. Parkinson, but they have not a ligneous endocarp with three pores as in the Cocoa-nut.

Mr. Bowerbank has shown that they are nearly related to the fruit of the NIPA, or Molucca-Palm, a tree which abounds in Bengal, and in the Molucca and Philippine Islands. The Nipæ are low, shrub-like plants, having the general aspect of palms; they grow in marshy tracts, at the mouths of great rivers, particularly where the waters are brackish. They are allied to the Cocoa-nut tribe, on the one hand, and to the *Pandanus*, or Screw-pine, on the other.

The *Nipadites*, according to Mr. Bowerbank, have the epicarp and endocarp thin and membranous, and the sarcocarp thick and pulpy, and composed of cellular tissue, through which run numerous bundles of vessels. Nearly in the centre of the pericarp is situated a large seed which, when broken, is more or less hollow. This seed consists of regular layers of cells, radiating from a spot situated near the middle, and apparently inclosing a central embryo.

The same author remarks, that "if the habits of the plants to which the fossil fruits belonged were similar to those of the recent *Nipa*, it will account for their abundance in the London Clay in the Isle of Sheppey; which formation, from the great variety of stems and branches, mixed up with star-fishes, shells of mollusks, and bones of fishes, crustaceans, and reptiles of numerous marine and fresh-water genera, is strikingly characteristic of the delta of a river, which probably flowed from near the Equator towards the spot where these interesting relics are deposited." The fact that the

seed-vessels of several species of Nipadites abound in the Isle of Sheppey, and have not been observed in any other locality in England, tends to support this opinion.

Carpolithes of this kind occur in great perfection in the Eocene strata of Belgium, and were figured and described, nearly seventy years since, in Burton's "*Oryctographie de Bruxelles*," as petrified cocoa-nuts; the uncompressed state in which these fossils occur makes the resemblance to the recent fruit more striking than in the flattened pyritous specimens from the clay of Sheppey.

The *Nipadites* of Brussels have recently been brought under the more immediate notice of English geologists, in a memoir "On the Tertiary Strata of Belgium and French Flanders," by Sir Charles Lyell, in which several specimens are figured and described.* These fossils are found in sands and sandstone, presumed to be of the age of the Bracklesham beds of Sussex. They are procured from Schaerbeek, in the northern suburbs of Brussels, where extensive quarries are worked for paving-stones, and have long been celebrated for remains of turtles, trunks of palms, and dicotyledonous trees, and the fruits, now called Nipadites. The vegetable remains often occur silicified; Sir C. Lyell was shown by the workmen "the trunk of a petrified exogenous tree, with forty rings of annual growth; it had lain in a horizontal position, and was bored by teredinæ. The silicified base of the trunk of a Palm-tree, apparently broken off short at about the level of the soil, had numerous air-roots, or rootlets, attached." †

Of the thirteen species of Nipadites enumerated by Mr. Bowerbank, some of which are, however, only accidental varieties, four have been identified among those obtained from Schaerbeek: two of them belong to but one species—

* Quarterly Journal of the Geological Society of London, vol. viii. August 1852.

† "On the Belgian Tertiary Formations," Geol. Journal, vol. viii. p. 344.

the *Nipadites Burtoni:* the others are *N. lanceolata* (*Lign.* 63, *fig.* 9), and *N. Parkinsoni* (*Pictorial Atlas*, plate vii.). These fossil nuts closely resemble the fruit of *Nipas fruticans*, a palm which abounds in the delta of the Ganges, and other parts of Bengal, and is the only living species of the genus known.* In an immature or abortive specimen of *Nipadites giganteus* (of Bowerbank), figured in *Geol. Journ.* pl. xix. fig. 2, the angularity of the pericarp observable in the ripe fruit (*Lign.* 63. *fig.* 9) is well marked. The largest specimen of Nipadites from Schaerbeek, is above seven inches long and four wide. The arenaceous strata containing these fruits, and stems of palms and dicotyledonous trees, are supposed to have been formed in the sea near the mouth of a river, as in the case of the clay-beds at Sheppey: the vegetable remains are associated with bones of fresh-water Turtles, teeth of Sharks, cases and spines of Echinoderms, and shells of the genera Ostrea, Pinna, &c.†

FOSSIL FRUIT OF PANDANUS. (*Popocarya. Bd.* pl. lxii. p. 503.) — The *Pandanaceæ* are monocotyledonous trees, named Screw Pines from the spiral insertion of their long, rigid, sword-like leaves, along the stem; they are natives of hot climates, and abound in the groups of islands in the Pacific; being generally the first important vegetable tenants of the newly-formed Atols or coral-islands. As in the palms, the stem is supported near the base by long side-roots, which enable these trees to maintain an erect position, and flourish on the newly-elevated coral-reefs, where but little soil has accumulated.

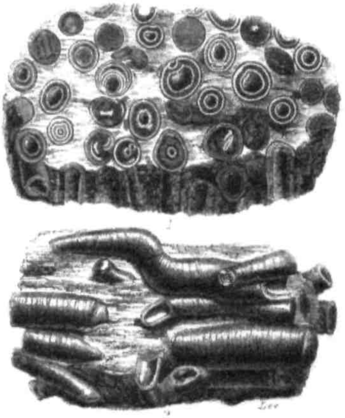
The existence of this tribe of plants during the secondary ages is known only by a single example of a fossil fruit,

* "On the Belgian Tertiary Formations," Geol. Journal, vol. viii p. 344.

† Geol. Journal, vol. viii. p. 347.

which was discovered by Mr. Page, of Bishport, in the Inferior Oolite, to the east of Charmouth, Dorsetshire, and is preserved in the museum at Oxford; no vestiges of the stems or foliage have been observed.

This carpolithe, (for a detailed account and figures see *Bd.* p. 504, pl. lxiii.) is of the size of a large orange; the surface is covered with a stellated epicarpium, composed of hexagonal tubercles forming the summits of cells which occupy the entire circumference of the fruit. Each cell contains a single seed, usually hexagonal, resembling a small grain of rice, and is supported by a foot-stalk, formed of dense fibres; a character exhibited only by the seed-vessels of Pandanus. The fossil fruit differs from that of the recent Screw-pines in the seeds being neither inclosed in a hard nut, nor collected into drupes, but dispersed uniformly over the entire mass; this forms the essential generic distinction between them. Dr. Buckland has named this unique carpolithe *Podocarya*. (*Bd.* p. 505.)



LIGN. 65. FOSSIL WOOD WITH TEREDINES; *nat.* *London Clay, Regent's Park.*

Fig. 1.—A polished transverse section, showing the tubes lined with spar.

2.—Portions of mineralized Teredines, seen in relief on the wood.

WOOD PERFORATED BY TEREDINÆ. *Lign.* 65.—The drifted trunks and masses of wood found in the London Clay, at Sheppey, Bognor, Bracklesham, &c., some of which belong to Palms, others to Conifers, and Dicotyledons, are commonly more or less perforated by the boring mollusks called

Teredo, or *Teredina*; and remains of their testaceous tubes are often well preserved. The tortuous channels excavated in the wood by these borers, are lined or filled up with calcareous spar, indurated clay, or other mineral matter, of various shades of grey, blue, yellow, &c.; and the polished slabs of this fossil wood are beautifully diversified by the sections of the sparry tubes, crossed at right angles by the ligneous structure; as in the specimen *fig.* 1, *Lign.* 65, from the Canal in the Regent's Park.*

In the fossil, *fig.* 2. *Lign.* 65, from the Isle of Sheppey, the tubes of the teredinæ are seen in relief, in consequence of the surface of the block of wood having decayed and been removed.

FOSSIL LILIACEÆ.—The family of endogens, termed *Liliaceæ*, comprises many beautiful plants; those with annual stems, as the Lily, Hyacinth, Tulip, &c. are well known for the variety and splendour of their blossoms; some of the arborescent forms, as the Tulip-tree, attain a large size, but the flowers of this division are relatively small. In tertiary strata, the stems, leaves, fruits, and even the imprints of flowers, have been discovered, of plants related to *Sagittaria* (Arrow-head), *Smilax* (Bind-weed), *Convallaria* (Lily of the valley), &c.

The Dracæna (*Dragon-blood tree*), a tall, slender, elegant tree with amplexicaul leaves (common in our hot-houses), belongs to this family; and certain stems found with Clathrariæ, and bones of the Iguanodon, in the Kentish-rag at Maidstone (*ante*, p. 173), so closely resemble the trunk of this plant, that they have been named by Mr. Konig,† *Dracæna Benstedi*; the specimens are in the British Museum. Until the internal structure of these fossils has been examined, the correctness of this identification is, however,

* Slabs of this kind are generally kept by the lapidaries at Bognor, Worthing, &c. and sold at 2*s.* or 2*s.* 6*d.* each.

† Petrifactions, p. 49.

uncertain: the external resemblance to the stem of the Dracæna consists in the interrupted annular ridges, denoting amplexicaul leaves: no vestiges of the foliage have been observed.

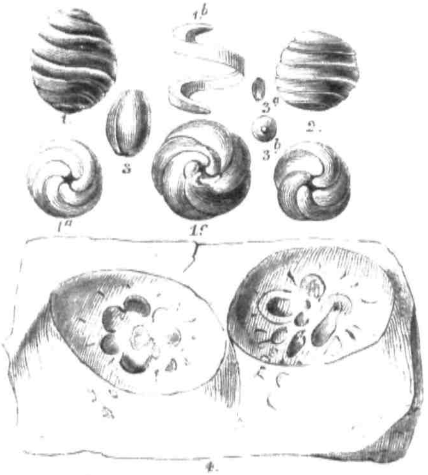
FOSSIL FRESH-WATER PLANTS.—The *tertiary* fresh-water strata often contain abundance of the remains of the aquatic vegetables that inhabited the lakes and rivers in which those deposits were formed. The remains of several species of the common lacustrine plant, the *Chara*, are found in immense quantities in the fresh-water limestones and marls of the Isle of Wight, of the coast of Hampshire, and of the Paris Basin. The shell-marls, still in progress of formation in the lakes of Scotland, and the travertine precipitated from thermal springs, in like manner envelop and preserve the leaves and fruits of recent species.

FOSSIL FRUITS OF CHARA. (*Gyrogonites.*) *Lign.* 66.—The Chara is a well-known inhabitant of almost every stream and rivulet. The stems are hollow, and composed of tubes filled with a fluid in which green globules circulate; they form beautiful microscopic objects for exhibiting the circulation in vegetables. The fruit consists of very small nuclei, contained in a calcareous pericarp, composed of five spirally twisted plates, that unite at the summit. These seed-vessels, when first discovered in a fossil state, were supposed to be the shells of mollusks, and a genus was formed for their reception with the name of *Gyrogonites* (*twisted-stones*); a term still employed, though the vegetable nature of these bodies is well known. In *Plate III. fig.* 5, a branch of the common Chara with seeds is represented: and figures of the seed-vessels of two fossil species are given in *Lign.* 66, *figs.* 1, 2.

Specimens of the fossil fruits and stems of Charæ, may be collected in abundance in the fresh-water limestone at East Cliff Bay, Isle of Wight.*

* See my Geology of the Isle of Wight, *Lign.* 5, p. 109.

The *Purbeck-beds* at Durlstone Bay, near Swanage, also contain numerous Gyrogonites associated with fresh-water



LIGN. 66. FOSSIL FRESH-WATER PLANTS.

Eocene, Paris.

Fig. 1.—Seed-vessel of *Chara helicteres* × 10; side view.
1a.—View of the base of the same.
1b.—One of the spiral valves separated.
1c.—View from above.
2.—Seed-vessel of *Chara medicaginula* × 10. The upper figure is a side view: the lower, a view of the base.
3.—*Carpolithes ovulum*, magnified side view.
3a.—The same, natural size.
3b.—Magnified view of the base of the same.
4.—A piece of fresh-water limestone, with impressions of two stems of *Nymphea arethusa* ×.

shells. The bands of siliceous sinter, which occur in the lowermost deposits, are especially rich in these remains.*

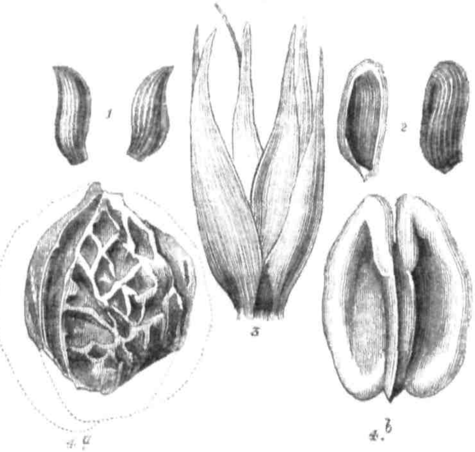
* I am indebted to the Rev. Osmond Fisher, of Dorchester, for a fine suite of these and other interesting fossils from the Purbeck beds of Ridgway and Osmington, near Weymouth; and to William Shipp, Esq., of Blandford, and Edward Woodhouse, Esq., of Ansty, for many specimens from Durlstone Bay, and Ridgway.

FOSSIL NYMPHEÆ. *Lign.* 66, *fig.* 4. — Those magnificent aquatic plants, the Water-Lilies (*Nymphea*), that adorn our rivers and lakes with flowers and foliage which partake more of the characters of an exotic flora than any other of our indigenous plants, are also found fossil in the lacustrine marls and limestones of the tertiary formations of France; but the nature of these remains could only be recognized by a profound botanist, for they consist of impressions of the internal structure of the stems, which, however, is so peculiar, that no reasonable doubt of their origin can be entertained. Two imprints on a piece of limestone from Lonjumeau, presented to me by the late M. Alex. Brongniart, are figured in *Lign.* 66, *fig.* 4; some minute seed-vessels (*Lign.* 66, *fig.* 3), found with them, closely resemble those of *Nymphea*, and are supposed to belong to the same plants (*Class. Vég. Foss.* p. 72).

FOSSIL FLOWERS.—The tertiary limestones of Monte Bolca (*Wond.* p. 565), so rich in ichthyolites, and other fossil remains of great interest, contain leaves, and even flowers, of liliaceous plants. The specimen figured (*Lign.* 67, *fig.* 3) is in the Museum at Paris, and described by M. Brongniart under the name of *Antholithes* (stone-flower) *liliaceus*; it consists of the corolla and calyx: the anthers and pistils have not been observed in any example. The discovery of this fossil should excite the young collector to search diligently for such objects in the tertiary strata of England.

FOSSIL ANGIOSPERMS. — The fossil remains of the class which constitutes the grand features of the existing floras of most countries, the *Exogenous Angiosperms*, are now to be considered; and though our survey of fossil botany has partaken but little of a geological arrangement, yet the reader may have observed, that a large proportion of the vegetables composing the floras of the ancient secondary formations, belonged to the Cryptogamous and Gymnospermous classes. A striking contrast is presented in the geo-

logical position of the mineralized dicotyledonous plants, of existing genera. These abound in the tertiary strata, and



LIGN. 67. FOSSIL NUTS, AND FLOWER.

FIG. 1.—THALICTROIDES PARISENSIS: Tertiary strata, Paris.
2.—THALICTROIDES WEBSTERI. Isle of Wight.
3.—ANTHOLITHES LILIACEUS. Monte Bolca.
4.—JUGLANS NUX-TAURINENSIS: fossil Walnut, Turin.
4a.—Portion of the husk of the shell.
4b.—The kernel, formed of calcareous spar.

generally in an inverse ratio to the antiquity of the deposit, while their remains are almost wholly absent in the older rocks; neither have there been discovered in the Tertiary, any beds of vascular cryptogamia, at all approaching the immense accumulations in the Carboniferous formations.

The most remarkable exception, is the single instance of a large leaf of a dicotyledonous plant in the Trias, or New Red sandstone, near Liverpool, described by Sir Roderick Murchison, which much resembles the foliage of a thick-ribbed Cabbage.*

* This fossil is named *Dictyophyllum crassinervium*, by Dr. Lindley, Foss. Flor. pl. cci. and is figured, Sil. Syst. p. 43.

It would be impossible, within the limits necessarily assigned to these volumes, to offer even a general view of the fossil remains of this grand class of vegetables; our remarks must be limited to a few interesting examples and localities.

When stems of *dicotyledonous trees only are found*, but little certainty can be obtained as to the family to which they belonged; the foliage of many well-known genera offer more positive characters; the flowers are rarely in a state of preservation to afford any valuable data; but the fruits, or seed-vessels, are frequently well preserved, and these may enable the botanist to arrive at precise determinations as to generic, and, perhaps, specific relations.

The tertiary marls of Aix, in Provence, which abound in insects, crustaceans, and lacustrine shells, contain many kinds of dicotyledonous leaves, associated with those of palms. (*Wond.* p. 260.)

The Lignite, or Brown-coal deposits, are almost entirely composed of dicotyledonous trees, belonging to many genera, which are inhabitants of Europe; namely, the Poplar, Willow, Elm, Chestnut, Walnut, Sycamore, Maple, Linden, Buckthorn, Vine, &c. (*Bd.* vol. i. pp. 508—514.)

The beds of brown coal, on the banks of the Rhine, are literally carbonized submerged forests, which in some remote period were drifted from the interior of the Continent into a vast lake or gulf; for the trees bear evident marks of transport, and are destitute of roots and branches. These masses resemble the rafts of forest-trees, which are daily floated down the Mississippi into the Atlantic, where they become engulfed in the profound depths of the ocean, and probably will be converted into coal or lignite; and in future ages, may be elevated above the waters, become dry land, and present to the then existing communities of mankind an inexhaustible supply of mineral fuel, composed of species and genera of plants, which possibly may

then be extinct, and replaced by peculiar types of vegetation.

FOSSIL FLORA OF ŒNINGEN. (*Bd.* pp. 511—514).—The celebrated lacustrine tertiary formation of Œningen, whose fossil reptiles and mammalia we shall have to notice hereafter, contains a rich assemblage of dicotyledonous and gymnospermous ligneous vegetables, with a few ferns and grasses. Not only branches and leaves of a species of Vine* occur, but even the fruit; fossil grapes being found in these deposits;† there are also many aquatic plants. A descriptive list of these fossils, by Professor Braun, of Carlsruhe, is given by Dr. Buckland. The brown-coal of this basin is in thin beds of but little economical importance, but so rich in the vegetation of the miocene tertiary period, that a few days spent in collecting those treasures will amply reward the intelligent tourist who may visit Constance. (See *Wond.* p. 263.)

The foliage of dicotyledonous trees frequently occurs in the Eocene marls and limestones, and in some localities in considerable abundance, and in beautiful preservation. Near Bournemouth, on the Hampshire coast, the leaves of many species are met with in a bed of sandy marl, between three and four feet thick: the vegetable substance is carbonized; some of the leaves are referable to the *Lauraceæ* and *Amentaceæ*, others to the *Characeæ*;‡ a similar deposit of tertiary plants has been discovered near Wareham. These beds belong to the lower group of the Hampshire Basin.§

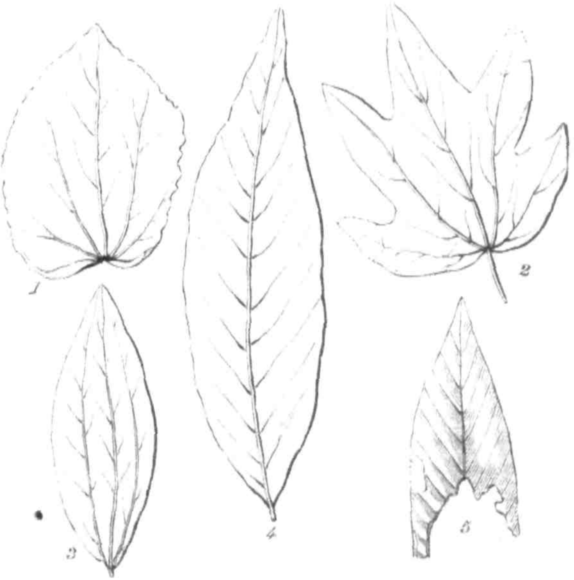
* See Knorr, Mon. des Catastrophes, pl. xxxviii. tom. i.

† Fossil grapes from the lignite of Œningen were exhibited by Dr. Daubeny at a late meeting of the Geological Society.

‡ Geol. Proc. vol. iii. p. 592.

§ As the seed-vessels and other vegetable remains in the Isle of Sheppey are all of a tropical character, while those found in the Eocene strata of Alum Bay, Bournemouth, and Newhaven, are of a temperate climate, as Nerium, Platanus, &c., Prof. E. Forbes infers that the former were transported from distant lands by currents, and that the latter belong to the true flora of the country inhabited by the Palæotheria and other associated mammalia.

The red marl-stone associated with lignite in the plastic clay beds at Castle Hill, Newhaven (*Geol. S. E.* p. 54),



LIGN. 68. IMPRINTS OF DICOTYLEDONOUS LEAVES IN GYPSEOUS MARL.
Tertiary. Stradella, near Pavia.

Fig. 1.—Leaf of Poplar (*Populus græca*).
2. ——— Maple (*Acer*).
3. ——— Water-spike (*Potamogeton*).
4. ——— Willow (*Salix*).
5. ——— Chestnut (*Æsculus*).

contains leaves of a similar kind; a seed-vessel of a coniferous tree has also been found in it.

Some of the most interesting examples of dicotyledonous leaves that have come under my notice, are from the Sub-Apennine tertiary strata, at Stradella, near Pavia. They belong to several genera of arborescent, or at least ligneous

plants, and most of them to species which still grow in Italy. In some examples the substance of the leaves is changed into carbon, and the structure well preserved; but, in general, sharp imprints on the stone are the only traces of the originals. They are found in a gypseous marl, of a cream colour; and, from their perfect state, it is inferred that they were enveloped in the soft matrix immediately after their fall, and preserved by the rapid crystallization of the gypsum. Two specimens from my cabinet are figured in *Plate III. figs.* 4 and 8; and outlines of a few other examples, in *Lign.* 68.

CARPOLITHES (*Fossil Fruits*).—In the description of the fossil fruits from the Isle of Sheppey, several kinds of dicotyledons were included. Many species also abound in the lignites of Germany, France, and Italy; in those near Frankfort, seed-vessels of the Maple, Elm, Hornbeam, Birch, Willow, and Walnut, &c. In the environs of Turin, fruits of a species of Walnut (*Juglans, Lign.* 67), occur in the newer tertiary deposits, and are called *Turin-nuts;* the ligneous envelope has perished, but the form of its surface, and of the inclosed kernel, is preserved in calcareous spar. These nuts differ, both in the pericarp and kernel, from the living species: the lobes are simple (*Lign.* 67, *fig.* 4[b]), and not subdivided as in the common walnut; a species has been discovered at Lons-le-Saulnier, in which the lobes are mamillated.

Two kinds of fruits belonging to plants of the order *Ranunculaceæ*, and related to *Thalictrum* (*Meadow-rue*), have been found in the eocene deposits of France and England; one in the Paris basin, (*meulière du terrain d'eau douce supérieur,*) by M. Alexandre Brongniart, and the other in the Isle of Wight, by Mr. Webster. In the specimen from the last-named locality the pericarp is carbonized, and its cavity filled with clay. Figures of these seed-vessels are given in *Lign.* 67, *figs.* 1, 2.

CARPOLITHES SMITHIÆ.—I would notice in this place some

very remarkable fossil fruits that are occasionally met with in the White Chalk of Sussex and Kent, and appear to belong to dicotyledonous trees. The first specimen was discovered by me in a chalk pit near Lewes, and is described in my "Fossils of the South Downs:" some illustrative examples collected by Mrs Smith, of Tunbridge Wells, tending to elucidate the nature of the original more satisfactorily than those in my collection, are figured and described by me in the Journal of the Geological Society, 1843, under the above name. These fruits are of an oval form, about one and a half inch long, and one inch wide, and are pressed almost flat. They are of a rich burnt-sienna colour, mottled with white, from the chalk having permeated their substance, and are studded over with slight eminences, which are the exposed summits of oblong flattened seeds. Although the internal structure is not preserved, there can be no doubt that the originals were spurious compound berries, having, like the Mulberry, the seeds imbedded in a soft pulpy mass.

FOSSIL DICOTYLEDONOUS TREES.—The occurrence of trunks and branches of angiospermous trees in a carbonized state has already been described; like the monocotyledons and conifers, they also occur silicified.

The most beautiful specimens I have seen are from the Lybian and Egyptian deserts, and were collected by my friend, the late Colonel Head. In these the most delicate vascular tissue is permeated by chalcedony and jasper, and the vessels are filled with silex of a bright vermilion and blue colour, while the cellular structure is of a rich yellow. Fragments of these fossil trees are scattered everywhere among the sands of the desert; the most interesting locality is an irregular plateau, which reposes on marine limestone, considerably above the level of the Nile, about seven miles east by south from Cairo. This district is called the *petrified forest*, from the immense quantities of silicified trees with which it is covered. It is thus graphically described by a late traveller:—

"Having passed the tombs of the Caliphs, just beyond the gates of Cairo, we proceed to the southward nearly at right angles to the road, across the Desert to Suez: and after travelling some ten miles up a low barren valley covered with sand, gravel, and sea-shells, fresh as if the tide had retired but yesterday, we cross a low range of sand-hills, which has for some distance run parallel to our path. The scene now presented is beyond conception singular and desolate. Heaps of fragments of large trees converted into stone every where meet the eye, and when struck by our horses' hoofs rang like cast iron; they extend for miles in the form of a decayed and prostrate forest; and the appearance is so natural, that were it in Scotland or Ireland, it would pass without remark as a drained bog, on which the exhumed trees lay rotting in the sun. The roots, and rudiments of the branches, are in many cases nearly perfect, and in some the worm-holes eaten under the bark are distinctly recognizable."*

Many of the trunks are scattered over the surface, among rolled and angular fragments of dark grit, and pebbles of jasper,† chert, and quartz. The large trunks occur in great numbers on dark-coloured knolls, where they lie, like the broken stems of a prostrate forest, crossing each other at various angles. Two of the largest measured respectively forty-eight, and sixty feet in length, and two and a half, and three feet in diameter, at the base. With but two or three exceptions, all the specimens examined microscopically, are dicotyledons. No traces of seed-vessels or leaves have been detected.

The situation and condition of these petrified forests, indicate great changes in the relative position of the land and sea in that part of Egypt; for the trees must have grown on the dry land formed by the elevated bottom of a former ocean; which must have subsided, and been covered by beds of sand

* Bombay Times.

† The jaspers are known to lapidaries as *Egyptian Pebbles.*

and pebbles; another elevatory movement must have raised the entire series of deposits to their present situation, and the retiring waters have removed the loose portions of the last formed strata, and dispersed them, with fragments of the silicified trees, over the surface of the Egyptian and Lybian deserts.*

DICOTYLEDONS OF THE CRETACEOUS EPOCH.—Among the crowd of interesting facts relating to the botanical character of the earlier periods of geology which recent observations have brought to light, one discovery demands especial notice, and I have reserved it for this place, rather than introduce it in an earlier section.

In the neighbourhood of Aix-la-Chapelle the lower members of the Cretaceous formation, viz. the Greensand, Galt, and Chalk-marl, are well developed, and comprise a series of littoral deposits of the great Chalk ocean that extended westwardly between France and England, on both sides of the existing Channel, and eastwardly over North and Central Germany, Sweden, Poland, and Russia, far into Asia. The series of strata at Aix-la-Chapelle is several hundred feet in thickness, and the lowermost beds lie immediately on the Carboniferous rocks of the country.

Dr. M. H. Debey,† to whose scientific labours we are indebted for an accurate knowledge of these interesting facts, divides these cretaceous deposits into four groups, the lowermost of which appears to be the equivalent of our Greensand; it consists of beds of clay and sand, the middle portion abounding in stems, leaves, and fruit, and the resin of coniferous trees.

The epidermis of the leaves often occurs in a carbonized state, and is recognizable by its microscopic structure.

* See a Memoir on the Geology of Egypt, Geol. Proc. vol. iii. p. 782; and on the Petrified Forest near Cairo, vol. iv. p. 349, by Lieut. Newbold, F.R.S.

† See Geol. Journal, vol. vii. p. 109.

Xylophagous mollusks are found in the petrified and carbonized wood. Fresh-water Desmidiaceæ, and a few marine remains, are associated with this fossil flora, which is distinguished by the abundance of Ferns and dicotyledonous leaves, and the scarcity of Cycads; among them are undoubted *Proteaceæ*.

The specimens collected by M. Debey from the lower cretaceous beds are the following:

Algæ, 15. Filices, 28. Hydropteridæ, 2. Cycadeæ, 5. Naiadeæ, 5. Palmæ, 1. Coniferæ, 20. Juliflore, 5. Credneriæ, 3. Leaves of Dicotyledons, undetermined, 26. Fruits undetermined, 8. Woods.*

This assemblage of angiosperms, with gymnosperms, and cryptogamia, at the commencement of the Cretaceous epoch, when the Iguanodon and other reptilian forms of the Oolite and Wealden still inhabited the land and water, proves, as Sir Charles Lyell has remarked,† that the meteorological phenomena of that remote period differed in no essential particular from those which now prevail.

RETROSPECT OF FOSSIL BOTANY.

IF we pass from the consideration of details of structure, and of botanical affinities, to a general survey of the mineralized remains of the vegetable kingdom, we perceive that from the palæozoic deposits, to those which are contemporaneous with the human race,—from the coal-measures to the peat bogs of modern times,—vast accumulations of vegetable matter, in various states of carbonization, have been produced from the imbedded relics of the terrestrial floras that flourished during the respective periods of their formation; petrifaction, or the transmutation of vegetable

* Geol. Journal, vol. vii. p. 111.

† Supplement to the New Edition of Elements of Geology, 1852, p. xv.

tissues into stone, from the infiltration of siliceous, calcareous, or metallic solutions, being an accidental process, dependent on the physical conditions under which the trees and plants were submerged, and entombed in the strata.

Although the entire system of vegetable life which prevailed during the earlier ages of the world is but partially revealed by the fossil remains which geological researches have brought under the examination of the naturalist,—for numerous tribes of plants may have existed of which no traces have been detected, while of species of delicate tissues all vestiges may have perished,—yet a review of the facts hitherto obtained, presents some highly important and unexpected results, as to the characters of the successive floras which prevailed during the palæozoic, secondary, and tertiary epochs. And though deductions of this nature must, in the present state of our knowledge, be regarded in the light of shifting hypotheses to be modified or abandoned with the progress of discovery,—yet the predominating types which characterize the flora of one system of formations, differ so essentially from those of another, that it may be reasonably inferred such apparent distinctions are the effect of organic laws, and not illusions arising from our misinterpretation of the natural records of former conditions of the vegetable world.

The absence in the most ancient deposits of the entire class of Angiosperms, or flowering plants, which constitutes the leading features of the floras with which we are familiar, —the abundance of unknown types of Cryptogamia, and the extinction or disappearance of those tribes in the succeeding formations, and the prevalence of new species and genera belonging to another class;—the predominance in one flora, both in number and variety, of certain tribes, and their decadence in the next period; while a family subordinate in the antecedent epoch, and known but by a small number of species, suddenly acquires a pre-eminence both in numbers

and variety ;—are phenomena, which the facts brought before us in the course of this argument, present in a striking point of view.

Assuming these data as the basis of a philosophical generalization, M. Brongniart arranges the known species of fossil plants into three grand systems, which correspond with the great geological periods, comprehended in the palæozoic, secondary, and tertiary formations.

The first or most ancient flora is characterized by the predominance of *Cryptogamic Acrogens*—the *Ferns* and *Club-mosses*; the second by the large development of the *Dicotyledonous Gymnosperms*—the *Cycads* and *Conifers*: the third by the appearance and prevalence of the *Angiosperms*, both dicotyledonous and monocotyledonous. The following table presents a concise view of the results of M. Brongniart's investigation.*

CHARACTER OF THE FLORAS.	GEOLOGICAL EPOCHS.
I. *Règne des Acrogènes*; the Flora of Vascular Cryptogamia.	The *Devonian*, *Carboniferous*, and *Permian*, Formations.
II. *Règne des Gymnospermes*; the Flora of Cycadaceæ and Coniferæ.	The *Triassic*, *Jurassic* (or *Lias* and *Oolite*), and *Wealden*, Formations.
III. *Règne des Angiospermes*; the Flora of Dicotyledonous and Monocotyledonous flowering plants, or Angiosperms.	The *Cretaceous*, and *Tertiary* (*Eocene*, *Miocene*, and *Pliocene*), Formations.

It must be observed that this table is only designed to indicate the successive *predominance* of each of the three classes of the vegetable kingdom, in the respective epochs, and not the entire exclusion of the others. Thus, in the two first, both Acrogens and Gymnosperms existed; but in the

* For details, and a masterly review of the subject, the original Memoir must be consulted. See Tableau des Genres de Végétaux Fossiles, considérés sur le point de vue de leur Classification Botanique et de leur Distribution Géologique, par M. Adolphe Brongniart. Paris. 1849.

first period the former greatly exceeded the latter, both in number and magnitude; while in the next the Gymnosperms acquired the ascendancy; but in both these epochs, from the Devonian to the Wealden inclusive, very few if any Angiosperms, or flowering dicotyledons, existed. With the Cretaceous period the Angiosperms appear in great numbers, and in the Tertiary epochs acquire the importance they possess in the existing floras.

The following analysis of the flora of the Carboniferous epoch, by M. Brongniart, will exemplify these remarks.*

ANALYSIS OF THE CARBONIFEROUS FLORA.

CRYPTOGAMIA (*Amphigens*).	Algæ	4	
	Champignons	2	
			6
(*Acrogens*).	Ferns	250	
	Lycopodiaceæ (Club-mosses)	83	
	Equisetaceæ	13	
			346
DICOTYLEDONOUS GYMNOSPERMS.	Asterophyllites	44	
	Sigillariæ	60	
	Nœggerathiæ	12	
	Cycadeæ?	3	
	Coniferæ	16	
			135
Dicotyledonous Angiosperms			0
Monocotyledons? (very doubtful)			15
			502

Thus out of five hundred species, 352 are Cryptogamia; and with the exception of six, belong to the Acrogens.†

* See Wonders of Geology, vol. ii. pp. 726—733, for an account of the Carboniferous floras and deposits.

† Bronn gives the annexed numerical summary of the fossil and recent species of plants:—

Plants.—Cellular	188	Fossil.	9,100 Living.
Vascular	1,867		60,303
	2,055		69,403 (80,000, Lindley.)

In conclusion, I must direct attention to a remarkable character of the palæozoic and secondary floras, namely, the almost entire absence of the *Gramineæ* or Grasses, which constitute so large a proportion of the existing vegetation.

Above six hundred species of plants have been discovered in the British strata;* and yet two species of *Poa* (a tribe of grasses), from Coalbrook Dale, are the only known examples of Gramineæ. It has been suggested that the greater or lesser durability of the foliage of certain vegetables, may have occasioned their presence or absence in the carboniferous deposits, and experiments were instituted by Dr. Lindley with the view of determining this question. But though it was found that, when the foliage of various families was subjected to long maceration, the leaves of dicotyledons and grasses disappeared, while those of ferns and cycads remained, this fact does not meet the exigencies of the case, for we have no evidence to show that the fossil leaves were ever placed in similar conditions; on the contrary, there is reason to conclude that they were imbedded under circumstances that arrested the usual progress of decomposition, prevented the escape of the hydrogen and other gaseous elements, and gave rise to the bituminous fermentation by which they were converted into lignite and coal; and we have no proof that, had grasses been associated with the ferns, they would not have undergone a similar change. Moreover, there are countries in which the ferns now assume the numerical proportion of the grasses of other latitudes; for example, New Zealand, which also presents in its fauna a striking analogy to that of the carboniferous deposits, in the almost entire absence of indigenous mammalia; one species of Rat being the only known living quadruped.

On this subject Dr. Dieffenbach remarks, that "although in its flora New Zealand has some relationship with the two large continents between which it is situated, America

* See Mr. Morris's Catalogue of British Fossils.

and Australia, and even possesses some species identical with those of Europe, without the latter being referable to an introduction by Europeans, yet the greater number of species, and even genera, are peculiar to it. New Zealand, with the adjacent islands, Chatham, Auckland, and Macquarrie, forms a botanical centre. It is sufficiently distant from both continents to preserve its botanical peculiarities, and it offers the most striking instance of an acknowledged fact in all branches of natural history, viz. that the different regions of the globe are endowed with peculiar forms of animal and vegetable life. The number of species of plants at present known is 632, of which 314 are dicotyledonous, and the rest, or 318, are monocotyledonous and cellular. The monocotyledons are few in comparison with the cellular plants, for there are but seventy-six species. The grasses have given way to ferns, for the ferns and fern-like plants are by far the most abundant in New Zealand, and cover immense districts. They *replace the Gramineæ* of other countries, and give a character to all the open land of the hills and plains. Some of the arborescent kinds grow to thirty feet and more in height, and the variety and elegance of their forms, from the minutest species to the most gigantic, are very remarkable."* In the accumulations of vegetable matter now in the progress of formation in the morasses, bays, and creeks of New Zealand, the remains of ferns largely predominate; and I am informed by my son,† that in the estuaries they are associated with numerous shells of brachiopodous mollusca.

ON COLLECTING BRITISH FOSSIL VEGETABLES.

From what has been advanced, the student will perceive that to obtain an illustrative collection of the fossil plants of Great Britain, many different localities must be visited.

* Dr. Dieffenbach's New Zealand.

† Mr. Walter Mantell, of Wellington, New Zealand.

The fruits and stems of Palms, Conifers, and many dicotyledons, may be collected in the Isle of Sheppey, and other places where the London Clay is exposed. (See *Excursion to the Isle of Sheppey*, Part IV.) Cycadeous stems and coniferous wood may be procured in the Isle of Portland; from the Wealden Cliffs along the southern shore of the Isle of Wight; and on the Sussex coast, from Bexhill, by St. Leonard's, to the east of Hastings. The foliage of several species of Zamiæ and ferns, occur abundantly in the lower Oolite, along the Yorkshire coast, near Scarborough, and at Gristhorpe Bay. The Lias of Lyme Regis, Charmouth, and their vicinity, affords stems and branches of coniferous trees, and leaves of cycads.

Ferns, Sigillariæ, Calamites, and the usual plants of the carboniferous flora, may be found in every coal-mine; and the Devonian limestones of the South of Ireland yield ferns and Lepidodendra. In Forfarshire the lower Devonian shales abound in the foliage of aquatic, apparently fluviatile, plants.*

A list of some of the most productive British localities is subjoined.

In addition to the suggestions already given as to the mode of collecting specimens, it may be necessary to state that the leaves in the tertiary marls and clays are generally very delicate and friable, and liable to flake off in the state of a carbonaceous film. This may, in a great measure, be prevented by carefully covering them with a thin coating either of mastic varnish, or gum-water, before they are placed in the cabinet. In extracting these specimens, a broad chisel will be found the most convenient instrument. In searching for fossils in coal-mines, the collector should remember that the ironstone nodules often contain beautiful examples of the leaves of ferns, and fruits of Lepidodendra. These nodules, when of an oblong shape, should be split open in a longitudinal direction, by a smart blow of a hammer,

* See Memoir on the TELERPETON; Geol. Journ. vol. viii. p. 106.

and the inclosed leaf will thus be exposed, as shown in *Lign.* 3, figs. 2, 3, *ante*, p. 69.

BRITISH LOCALITIES OF FOSSIL VEGETABLES.

Allenbank, Berwickshire . .	*Carb.* . .	Stems of Conifers, &c.
Alum Bay, Isle of Wight .	*Tert.* . . .	Fruit, dicotyledonous leaves, lignite; Charæ, stems and seed-vessels.
Ashby-de-la-Zouch, Leicestershire.	*Carb.* . .	Coal plants in great abundance.
Bignor, Sussex.	*Cret.* *Firestone*	Fucoids.
Binstead Quarries, near Ryde, Isle of Wight . . .	*Tert.* . . .	Charæ, stems and seed-vessels.
Blackdown, Devonshire . .	*Gr. Sand*	Silicified wood—coniferous.
Bognor, Sussex	*Tert.* . . .	Coniferous and monocotyledonous wood; washed up on the shore.
Bolton, Lancashire	*Carb.* . .	Lepidodendra, Sigillariæ, &c.
Bournemouth, Hants	*Tert.* . . .	Dicotyledonous leaves.*
Brook-point, Isle of Wight.	*Wealden.*	Cycads, and coniferous wood.
Burdie House, near Edinburgh	*Carb.* . .	Ferns, wood, &c.
Calbourn, Isle of Wight . .	*Tert.* . . .	Charæ, stems and fruits.
Camerton, near Bath	*Carb.* . .	Usual plants of the coal.
Charmouth, Dorset	*Oolite* . .	Coniferous wood; Cycads; fruit of Pandanus.
Clifton, near Manchester . .	*Carb.* . .	Coal plants in great perfection.
Coalbrook Dale, Shropshire	*Carb.* . .	Usual plants of the coal, in abundance. The ironstone nodules are rich in fern-leaves, fruits of lepidodendrons, &c.
Cuckfield, Sussex	*Wealden.*	Clathraria, Endogenites, Ferns, and Lignite.

* Fruits and Fern-leaves have been collected here by Mr. Beckles and stems of a species of *Arundo*, by Mr. Alfred Woodhouse.

Durlstone Bay, near Swanage.	*Wealden.*	Charæ; *Gyrogonites* in abundance.
Folkstone, Kent	*Galt* . . .	Coniferous wood—bituminous, and pyritified.
Glasgow	*Carb.* . .	Coal plants, and large trunks of Coniferæ.
Hastings, Sussex	*Wealden.*	Clathrariæ, Cycads, Endogenites, Ferns, Thuites, &c.
Herne Bay, Kent	*London Clay* . .	Fruits of Conifers, and Palms: wood.
Kilkenny, Ireland	*Carb.* . .	Calamites, ferns, &c.
Knocktopher, nr. Kilkenny, Ireland	*Devonian*	Ferns, Lepidodendrons, &c.
Leeds	*Carb.* . .	Beautiful coal-plants from the pits in the vicinity.
Liverpool	*New Red*	Fuci.
Lyme Regis, Dorset	*Lias* . . .	Cycads; Conifers; wood.
Maidstone, Kent	*Green-Sand* . .	Fruits and wood of Abies, Pinus, Dracæna; Fuci.
Malton	*Oolite* . .	Fruits, and Cycads.
Newcastle (Jarrow Colliery)	*Carb.* . .	Coal plants in great variety.*
Newhaven (Castle Hill), Sussex	*Tert.* . . .	Dicotyledonous leaves and fruit—*rarely.*
Portishead (on the shore) .	*Millstone Grit* . .	Sigillariæ, Stigmariæ, &c.
Portland, Isle of	*Wealden.*	Petrified forest of Conifers, with Cycads.
Pounceford, Sussex	*Wealden.*	Equiseta, Ferns, Lignite.
Runswick, Yorkshire Coast	*Lower Oolite.* .	Cycads, Ferns, &c.
Saltwick, near Whitby . . .	*Lower Oolite.* .	Foliage of Cycads, Ferns, &c.
Sandown Bay, Isle of Wight	*Wealden.*	Conifers, Cycads, wood.
Scarborough	*Oolite* . .	Ferns, Cycads, Equiseta, &c.
Selmeston, Sussex	*Green-Sand* . .	Coniferous wood.

* In collecting *Stigmariæ*, the student should particularly attend to the relation existing between these fossils and their supposed stems; for it is probable that roots of this type will be found to belong to other genera, besides Sigillaria, and Lepidodendron (*ante*, p. 136).

Sheppey, Isle of	*London Clay* . .	Fruits innumerable, wood, &c. (*ante*, p. 186.)
Stonesfield, Oxfordshire . .	*Oolite* . .	Fuci, Cycads, Thuites, &c.
Swindon, Wilts	*Oolite* . .	Coniferous wood, & Cycads.
Tunbridge Wells (vicinity).	*Wealden*.	Ferns, several species.
Ventnor, Isle of Wight . .	*Firestone*	Clathraria, Conifers.
Wareham, Dorset	*Tert.* . . .	Dicotyledonous foliage, and Palm-leaves.
White-Cliff Bay, I. of Wight	*Tert.* . . .	Palm-leaves, Charæ, &c.
Whitwick, Leicestershire. .	*Carb.* . .	The usual coal-plants.

The above list must, of course, be considered as merely suggestive: many other localities are mentioned in the previous notices of the fossil genera.

PART III.

FOSSIL ZOOLOGY.

"THE very ground on which we tread, and the mountains that surround us, are vast tumuli in which the Organic Remains of a Former World are enshrined."—PARKINSON.

THE existing species of animals scientifically determined by naturalists amount to upwards of one hundred thousand, while those known in a fossil state scarcely exceed twenty-five thousand; yet the latter comprise examples of all the classes, and most of the families and genera, which still inhabit our planet. Although our notice of these remains must necessarily be very general, we shall endeavour to describe all that are of peculiar interest, either in a geological or zoological point of view; or which from their prevalence, or wide distribution, will frequently be met with by the collector in the course of his researches.

Our examination will commence with animal organisms of the simplest structure, and proceed in an ascending order, in accordance with the usual zoological classifications; but, as in the botanical department, it will be convenient occasionally to include the consideration of the fossil remains of more than one family in the same section, when associated in a particular locality or deposit.

In the preliminary remarks on the nature of Organic Remains (*ante*, p. 43), the various conditions in which the

durable structures of animals are preserved in the mineral kingdom, were fully explained; we may therefore at once enter upon the investigation of this most important division of our subject; that to which the term *Palæontology*, is, indeed, restricted by some authors.

The fossil remains of the animal kingdom will be treated of under the following heads:—

I. Zoophytes: including—
  1. Porifera, or Amorphozoa: the most simple animal structures; as the *Sponges*.
  2. Polypifera, or Polypiaria; *Coral-animals*.
  3. Bryozoa, or *Molluscan Zoophytes;* as the *Flustræ*.

II. Echinodermata, or Echinoderms; comprising—
  1. Crinoidea; or Lily-shaped animals.
  2. Asteriadæ; *Star-fishes*.
  3. Echinidæ; *Sea-urchins*.

III. Mollusca, or Mollusks. Under this head not only the fossil shells of testaceous mollusca, but also those of a lower order of animals, the *Rhizopodes*, or *Foraminifera*, will be treated of.
  1. Foraminifera.
  2. Bivalves: the Lamellibranchia, and Brachiopoda.
  3. Univalves: the Gasteropoda and Pteropoda.
  4. Cephalopoda; those with chambered shells, as the *Nautilus* and *Ammonite;* and the naked tribes, the Sepiadæ, or *Cuttle-fish*.

IV. Articulata. (Animals protected by a hard jointed envelope or case.)
  1. Cirripedia: as the *Balanus*, or Barnacle.
  2. Annelida: red-blooded worms, as the *Serpulidæ*.
  3. Insecta, and Arachnida or *Spiders*.
  4. Crustacea; including *Crabs, Lobsters, Trilobites,* &c.

V. Pisces; or Fishes.

VI. Reptilia; or Reptiles.

VII. Aves; or Birds.

VIII. Mammalia.

IX. Man.

CHAPTER VII.

FOSSIL ZOOPHYTES.—PORIFERA OR AMORPHOZOA—POLYPIFERA OR CORALS—BRYOZOA OR MOLLUSCAN ZOOPHYTES.

MANY tribes of the extraordinary beings whose mineralized relics are the immediate subject of our investigation, have largely contributed to the solid materials of which the sedimentary strata are composed. In the most ancient rocks in which vestiges of organic structures have been detected, those of *Zoophytes* hold a conspicuous place; and in the seas of tropical climates, the agency of the Coral-animalcules, or Polypifera, is producing enormous deposits, and laying the foundations of new islands and continents, and forming reefs of rocks hundreds of miles in extent, which, if elevated above the level of the sea, would rival in magnitude the mountain chains of modern Europe.

The reader unacquainted with the natural history of these marvellous creatures will find an account of their nature and economy, and of the physical effects produced on the earth's surface by their agency, in the sixth lecture of *Wond.* vol. ii. p. 588.

The term Zoophytes, or animal-plants, comprises two very distinct classes of living beings, namely, the PORIFERA, or Sponges, which (if not vegetables) are wanting in many attributes regarded as essential characteristics of the members of the animal kingdom; and the POLYPIFERA, or polype-bearing-animals,—the Corals; which are generally associated groups or aggregations of individuals, united by a common organ-

ized mass or axis, each polype having an independent existence, and exhibiting volition and perception, in a greater or lesser degree.

Fossil Porifera.

The terms *Amorphozoa* (signifying animals of variable shapes), and *Porifera* (structures traversed by pores or channels), are employed by naturalists to designate the Sponges and analogous organisms, which appear to occupy the boundary line that separates the animal from the vegetable kingdom. The true position of the Sponges in the great system of Creation is still a disputed point; for while many distinguished naturalists regard them as *Protozoa*, or the lowest type of animal organization, others of equal eminence affirm that neither in structure nor functions do they differ from vegetables in any essential particular; and that if a line be drawn between the two kingdoms the Porifera must be placed on the vegetable side of the boundary. On the other hand, Dr. George Johnston, in his delightful work on the British Zoophytes,* expresses his opinion that there is nothing to discountenance the belief that these bodies hold an intermediate place; that they are, in fact, the true *Zoophytes*, or animal-plants; in some forms, as the green *Spongillæ* of our lakes, the vegetable nature prevails; while in others, as the horny or keratose sponges filled with mucilaginous slime, and the fleshy *Tethya* whose oscula, or pores, are said to exhibit signs of irritability, the animal character predominates.

Without committing ourselves to either opinion, and simply remarking that the large proportion of silex that enters into the tissues of a considerable number of the porifera,

* A History of British Sponges, &c. by Dr. George Johnston, Edinburgh, 1843. One vol. 8vo. with twenty-five plates. A previous work, "A History of British Zoophytes," with forty-four plates, from drawings by the accomplished lady of the Author, cannot be too highly commended.

is more characteristic of vegetable than of animal structures, we proceed to consider the fossil sponges and allied forms, as the mineralized remains of the lowest types of the animal kingdom : if the vegetable nature of the originals were generally admitted, this section should have followed that which treats of the Diatomaceæ (*ante*, p. 100).

Sponge consists of a reticulated fibrous mass, covered with numerous pores of various sizes, which are connected internally by anastomosing channels, and this tissue is surrounded by a cellular gelatinous matter, by which the entire structure was secreted, and is, in fact, the vital part of the zoophyte. The tough framework or skeleton is in some kinds fibrous, horny, flexible, or rigid, and strengthened by calcareous or siliceous spicula (*spines*) ; * while in other species its substance is calcareous, and in some siliceous, constituting a web of transparent rock crystal, resembling spun glass.† The gelatinous matter lines all the cavities, and forms the margins of the openings ; it presents no signs of irritability, and may be easily pressed out of the porous mass with the hand, so slight is the connexion between the skeleton and the investing tissue. Currents of water constantly enter the small pores, traverse the inosculating canals, and issue from the larger orifices, which often project above the surface in perforated papillæ. By the circulation of the water through the porous structure, the nutrition of the organized mass is effected ; and the modifications observable in the number, size, form, and disposition of the pores, channels, and orifices, in different species, appear to be subservient to this especial

* The Mediterranean and American sponges of commerce are devoid of spicules, and are deprived of their soft animal matter simply by washing freely in fresh water.

† I particularly allude to a siliceous Sponge from Barbadoes, named, by Mr. Samuel Stutchbury, formerly of the Bristol Institution, (now of Australia,) *Dictyochalix pumicea*. This specimen is of a fungiform shape, and appears to the naked eye as if formed of pumice stone, but under the microscope is literally a tissue of transparent silex.

purpose; the imbibition and expulsion of water being the only function the sponges perform. In its earliest stage the sponge gemmule is of a spheroidal shape, and covered with vibratile cilia, and after expulsion from the canals in which it is formed, moves rapidly through the water till it becomes attached to some body, and is then immovably fixed during life; exhibiting no signs of vitality save the aqueous circulation through the pores and canals.

There is much confusion in the arrangement and nomenclature of the fossil species of this class of zoophytes; and this has originated, in part, from the varied forms assumed by the same species, having been described under different names; and from the reprehensible practice of changing, without sufficient reason, the name assigned to a species by the original discoverer; an evil, unfortunately, not restricted to this department of natural history.

The recent Sponges are arranged in four groups according to their structure, viz.—

Fresh-water Sponges.

SPONGILLA: siliceous spicula in a translucent jelly-like mass.

Marine Sponges.

TETHEA: having a tough outer skin; siliceous spicula in bundles, and radiating from the compact nucleus to the periphery.

HALICHONDRIA: (from *silex* and *cartilago*) siliceous spicula in a cartilaginous mass.

GRANTIA: calcareous spicula in a gelatinous mass.

M. D'Orbigny seems to believe that with the exception of the horny *Cliona*, all the fossil sponges had originally calcareous skeletons,—"qu'ils n'ont jamais été cornés, mais que leur tissu a toujours été calcaire et pierreuse;"* which is certainly not the case, for abundant examples of fossil keratose sponges occur.

* Cours Elémentaire de Paléontologie, tom. ii. p. 208.

I have selected a few genera for the illustration of the subject, and shall describe them under the names that are most familiar to the British scientific collector: doubtless sooner or later some competent naturalist will undertake the elucidation of this department of palæontology, and construct a classification and nomenclature based on natural characters; till then the student will find it hopeless to attempt to learn the ever-varying names of genera and species applied to fossil Porifera and Polypifera, by different observers.*

ON THE SPONGES IN CHALK AND FLINT.—From the durability of the tissue of the flexible sponges, and the imperishable nature of those which have a siliceous or calcareous endoskeleton or framework, their fossil remains generally occur in a fine state of preservation, and in immense quantities, in the sediments that were deposited in those parts of the ancient sea-bottoms, originally inhabited by these zoophytes. Even the relics of the keratose species, the *Halichondria*, whose structure consists of siliceous spines imbedded in a cartilaginous mass, are equally abundant. Sponge-spicula are everywhere met with in the chalk, flint, and greensand, and many layers in the cretaceous strata are almost entirely composed of them.

Sponges so commonly form the nuclei of the nodular flints, that some naturalists have ascribed the formation of the layers and nodules of silex in the cretaceous rocks to these zoophytes: a supposition altogether groundless.† The various

* It has happened most unfortunately, that but recently Mr. Lonsdale, in the late Mr. Dixon's beautiful work on Chalk and Tertiary Fossils, and Mr. Milne Edwards in his able Monograph in the Palæontological Society's Memoirs, have described many of our chalk Corals under different specific and generic names.

† See Wonders of Geology, p. 300. This question is fully considered in a Memoir entitled Notes of a Microscopical Examination of the Chalk and Flint of the South-East of England, &c. by the Author, in 1845.

states of mineralization in which sponges occur in the chalk give rise to many beautiful and highly instructive fossils, as we shall point out in the course of this notice. In general the zoophyte is simply invested by the flint, the pores and tubes being filled with silex, the original tissue appearing as a brown reticulated calcareous mass. In other examples the sponge has been permeated by the liquid flint, and subsequently perished; and in this manner have been formed those hollow nodules which on being broken are found to contain only a powder, consisting of siliceous spicules and fragments of silicified sponge. But in numerous instances the substance of the zoophyte is completely silicified, and the intimate structure of the original exquisitely preserved; such are many of the flint-pebbles, and moss-agates, that are mounted as brooches and other ornaments.

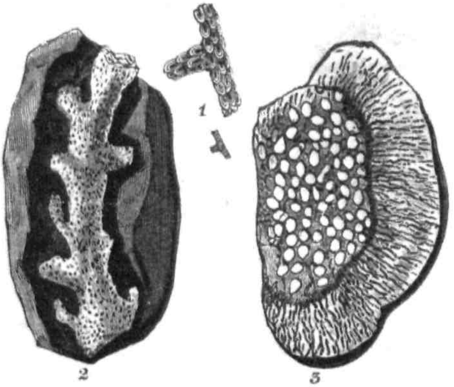
SPONGITES.*—This name I would apply generically to those fossils which appear to be identical in structure with the ordinary marine sponges that consist of a fibro-reticulated porous mass, destitute of regular tubes or canals: the form exceedingly various.

The fossil sponges of the chalk may be divided into two groups; the cyathiforms, or cup-shaped, and the ramose, or branched. Flints inclosing the first kind, generally exhibit externally the form of the original; those containing the branched species are of irregular shapes, and except by an experienced observer, the nature of the enclosed body would not be suspected. On breaking them, the sponge is often well displayed, as in the specimen figured in *Lign.* 69, *fig.* 2: the surface of this fossil was covered with a white gritty powder, made up of minute needle-shaped siliceous spicula.

SPONGITES RAMOSUS.—A branched sponge, sometimes from twelve to fifteen inches long, is not uncommon in the flints of the Lewes and Brighton chalk; the stems and branches are cylindrical, and the terminations of the latter are rounded

* *Achilleum* of Schweigger.

and full of large pores. When completely silicified the structure can only be detected by fracture, but occasionally the sponge appears to have been saturated with liquid chalk before it was enveloped in the flint; and as it is coated with calcareous matter, it may be detached from the nodule entire.*



LIGN. 69. CORAL, AND SPONGITES.
Chalk. Sussex.

Fig. 1.—PETALOPORA PULCHELLA. Upper figure × × : lower figure, *nat. Chalk near Chichester.* (*Mr. Walter Mantell.*)

2.—SPONGITES CLAVELLATUS. A branch in the cavity of a flint. *South Downs.*

3.—SIPHONIA MORRISIANA. (G. A. M.) A transverse polished section of a pebble. *Brighton Beach.*

A smaller ramose spongite, with numerous short clavate protuberances, is often met with in the flints of Sussex and Wilts; a branch is figured in *Lign.* 69, *fig.* 2.†

* In this manner I obtained the beautiful specimen (now in the British Museum) figured in my Foss South Downs, tab. xv. fig. 11. A branch of this species is represented Pict. Atlas, pl. xxxix. fig. 12. *Spongites lobatus* (sp. Fleming) is figured Pict. Atlas, pl. xxxix. fig. 6.

† This spongite is named Polypothecia clavellata, in Miss Benett's Wiltshire Fossils.

Spongites Townsendi. (*Pict. Atlas*, pl. xli.)—The cyathiform flints, whose shape depends on the inclosed zoophytes, so much resemble the cup-shaped sponges of commerce, as to be easily recognized in the heaps of nodules that are collected in chalk districts for the roads; they are from one to eight inches in diameter at the upper part, and many are of a globular or spheroidal shape; the surface has the usual calcareo-siliceous coating of flint nodules, giving a sensation of roughness to the touch; the margin of the cup generally exhibits a narrow band of porous structure, and when broken, sections of the enclosed body are exposed. These funnel-shaped spongites terminate at the bottom in a peduncle, whence fibrous root-like processes diverge; by these appendages the original was fixed to the rock. I have collected a few specimens in which the roots are attached to a shell, or pebble, but have never seen any that appeared to occupy the spot on which they grew. They seem to have been detached from their native sites by the waves, and transported to a distance, and subsiding into the tranquil depths of the ocean, became imbedded in the cretaceous sediments that were accumulating at the bottom.

Spongites (?) labyrinthicus.* *Lign.* 80, *fig.* 5.—Another abundant species of amorphozoa has given rise to subhemispherical flints, rounded below and flat above, with a marginal band of porous tissue, that expands into flexuous lobes which fill up the area of the upper surface. When found imbedded in the chalk, the form of this zoophyte is often preserved entire; the upper part showing the lobated and flexuous character of the original. Upon breaking these flints, the organic structure is generally apparent; but in many instances has perished, and left a cavity which is either partially filled with stalactitical chalcedony, or lined with quartz crystals. These fossils vary in size from a walnut to that of an orange; the pedicle has long processes.

* Foss. S. D. tab. xv. fig. 7.

A lobed zoophyte, resembling the above in its general form, and long rootlets, is distinguished by a large central cavity, which is continued above the body in the form of a *cylinder.**

SPONGITES (?) FLEXUOSUS. *Lign.* 80, *fig.* 10.—Among the cyathiform flints that abound in the chalk, a very elegant species is distinguished by a flexuous band that runs round the margin, and indicates the lobed structure of the original.

In the chalk of Flamborough Head, Yorkshire, many beautiful cyathiform sponges are preserved, in which the outer surface is thickly covered with projecting hollow papillæ; these fossils are generally silicified, the surface and pores being frosted over with minute quartz crystals. The museum of the York Institution contains a splendid series of these spongites.†

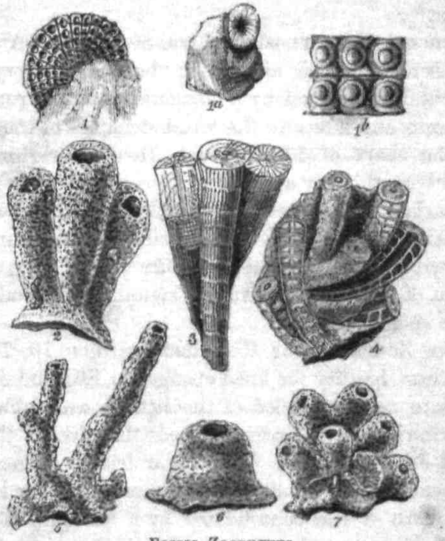
FOSSIL ZOOPHYTES OF FARINGDON. *Lign.* 70, 71, 72.—The richest locality for fossil sponges in England is in the immediate neighbourhood of the little town of Faringdon, in Berkshire ‡. The Greensand beds that overlie the Oolite in that district, consist of a coarse friable aggregation of sand, comminuted shells, corals, amorphozoa, and echinoderms, more or less consolidated by a ferruginous cement. The gravel-pits, as the quarries are locally termed, expose what evidently were banks of detritus thrown up on the strand of a sea-margin; among the waterworn and fragmentary relics of oolitic as well as cretaceous forms, many perfect

* Beautiful figures of these and other chalk zoophytes are given by Mr. Toulmin Smith in his elegant memoir "On the Ventriculidæ." The specimens above described are named *Brachiolites* by Mr. Smith. The plan of the present work forbids the discussion of that author's opinions and inferences.

† The silicified state of these zoophytes was first detected by Mr. Charlesworth, who by immersing specimens in dilute hydrochloric acid, obtained admirable examples of the delicate structure of the original.

‡ See Excursions, in vol. ii.

sponges of various kinds may be collected in the course of a few hours. Figures of some of the common species are subjoined.



LIGN. 70. FOSSIL ZOOPHYTES.

Fig. 1.—LUNULITES RADIATUS. *Preston Chalk-pits;* view of the convex side. (*Mr. Walter Mantell.*)

1a.—Front view; *nat.*

1b.—Portion of the surface of fig. 1, magnified.

2.—SCYPHIA INTERMEDIA; ½ *nat.* *Faringdon.*

3.—LITHODODENDRON SOCIALE: the left-hand branch shows a vertical section at the upper part, displaying the internal structure; ⅓ *nat.* *Mountain Limestone, Yorkshire.*

4.—VERTICILLIPORA ANASTOMOSANS. *Faringdon.*

5.—SCYPHIA RAMOSA; ½ *nat.* *Faringdon.*

6.—SCYPHIA FORAMINOSA; ½ *nat.* *Faringdon.*

7.—CNEMIDIUM ASTROPHORUM; ½ *nat.* *Faringdon.*

SCYPHIA. *Lign.* 70, 72.—These spongites are of a tubular, fistulous, or cylindrical form, and terminate in a rounded pit; they are either simple or branched, and composed of a firm reticulated tissue; *Lign.* 70, *fig.* 2, 5, 6, and *Lign.* 72,

fig. 4, are examples. The Upper Greensand at Folkstone and Dover abounds in a flexuous species, named *Scyphia meandrina* (*Morris*).

CNEMIDIUM (*Goldfuss*). *Lign.* 70, *fig.* 7.—These sponges consist of a cluster of turbinated projections, having a central pit above, and being porous on the external surface, and radiated at the margin. The mass is dense and fibrous, and is traversed by horizontal canals, diverging from the centre to the circumference.

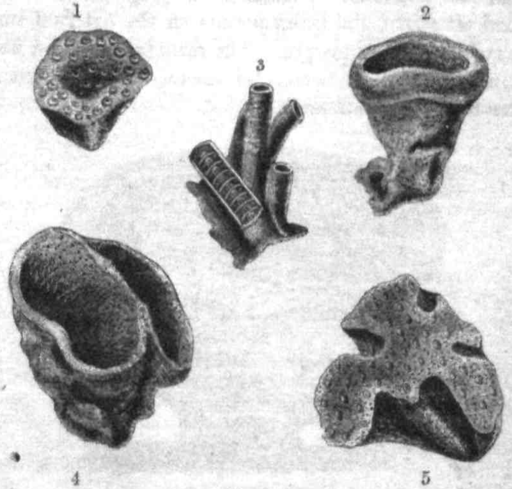
LIGN. 71. FOSSIL SPONGE; *nat.*
(Chenendopora fungiformis.)
Greensand. Faringdon.

CHENENDOPORA.* *Lign.* 71.—The species of porifera thus named are cyathiform, or cup-shaped; externally furrowed, mamillated, or lobed; internally smooth, and the surface covered with fine pores. The beautiful species figured (*C.*

* The Pictorial Atlas contains coloured figures of the following:—
Chenendopora fungiformis (*Michelin*), Pict. Atlas, pl. xliv. fig. 5: *according to Mr. Morris.*
———— subplana (*Michelin*), ibid. pl. xliv. fig. 3.
Scyphia articulata (*Goldfuss*), ibid. pl. xliii. figs. 7, 8, 9.
———— costata (*Goldfuss*), ibid. pl. xliv. fig. 1.
Cnemidium rimulosum (*Goldfuss*), ibid. pl. xliv. fig. 3.

fungiformis) is abundant in the gravel-pits, and well known to the quarrymen as "*petrified salt-cellars.*"

TRAGOS. *Lign.* 72, *fig.* 1.—These turbinated sponges are readily distinguished from the preceding, by the relatively



LIGN. 72. FOSSIL ZOOPHYTES; *nat.*
Greensand. Faringdon.

Fig. 1.—TRAGOS PEZIZA.
2.—Probably CHENENDOPORA in a young state.
3.—VERTICILLIPORA ANASTOMOSANS.
4.—Species of SCYPHIA.
5.—TRAGOS FARINGDONIENSIS.

large oscula, or open papillæ, disposed irregularly on the inner surface; as shown in the specimen, *fig.* 1. Their tissue is dense and fibrous. The fossil represented by *fig.* 5, though named *Tragos* by collectors, appears to differ in the structure of the inner surface from the type of this genus: it is a remarkably beautiful species.*

The base in all these Greensand sponges is flat and

* It may be convenient to distinguish it as *T. Faringdoniensis.*

fig. 4, are examples. The Upper Greensand at Folkstone and Dover abounds in a flexuous species, named *Scyphia meandrina* (*Morris*).

CNEMIDIUM (*Goldfuss*). *Lign.* 70, *fig.* 7.—These sponges consist of a cluster of turbinated projections, having a central pit above, and being porous on the external surface, and radiated at the margin. The mass is dense and fibrous, and is traversed by horizontal canals, diverging from the centre to the circumference.

LIGN. 71. FOSSIL SPONGE; *nat.*
(Chenendopora fungiformis.)
Greensand. Faringdon.

CHENENDOPORA.* *Lign.* 71.—The species of porifera thus named are cyathiform, or cup-shaped; externally furrowed, mamillated, or lobed; internally smooth, and the surface covered with fine pores. The beautiful species figured (*C.*

* The Pictorial Atlas contains coloured figures of the following:—
Chenendopora fungiformis (*Michelin*), Pict. Atlas, pl. xliv. fig. 5: according to Mr. Morris.
———— subplana (*Michelin*), ibid. pl. xliv. fig. 3.
Scyphia articulata (*Goldfuss*), ibid. pl. xliii. figs. 7, 8, 9.
———— costata (*Goldfuss*), ibid. pl. xliv. fig. 1.
Cnemidium rimulosum (*Goldfuss*), ibid. pl. xliv. fig. 3.

fungiformis) is abundant in the gravel-pits, and well known to the quarrymen as "*petrified salt-cellars.*"

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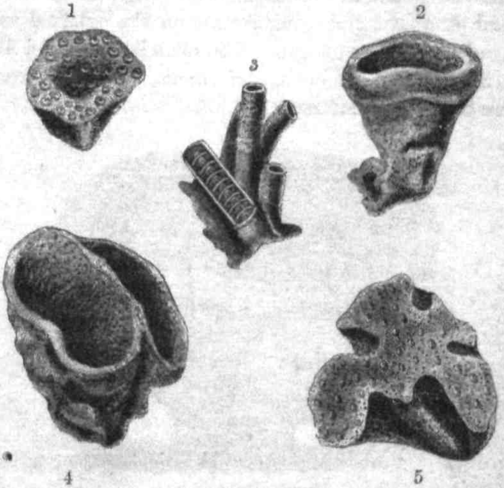

LIGN. 72. FOSSIL ZOOPHYTES; *nat.*
Greensand. Faringdon.

Fig. 1.—TRAGOS PEZIZA.
2.—Probably CHENENDOPORA in a young state.
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large oscula, or open papillæ, disposed irregularly on the inner surface; as shown in the specimen, *fig.* 1. Their tissue is dense and fibrous. The fossil represented by *fig.* 5, though named *Tragos* by collectors, appears to differ in the structure of the inner surface from the type of this genus: it is a remarkably beautiful species.*

The base in all these Greensand sponges is flat and

* It may be convenient to distinguish it as *T. Faringdoniensis.*

expanded; not fibrous and root-like, as in the spongites of the chalk previously described.

Among the shingle at Brighton, Margate, Dover, Isle of Wight, &c. pebbles containing fossil sponges may frequently be discovered. When the flint nodule has been broken, and the calcareous particles of the inclosed zoophytes are washed away by the action of the waves, a delicate silicified tissue remains.* Many of the large solid pebbles, are portions of silicified sponges, and polished specimens are beautiful objects under the microscope.

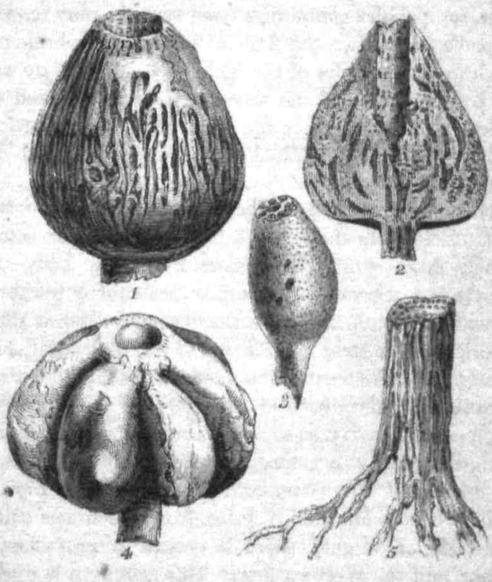
SIPHONIA. *Lign.* 73.—These fossil porifera are readily distinguished from those which have engaged our attention by their more symmetrical structure. The body of the zoophyte is a mass of dense porous tissue, of a pyriform or bulbous shape, supported by a slender stem fixed at the base by rootlets. The stem is composed of very fine parallel longitudinal tubes, which extend to a series of canals that traverse the mass, and terminate in openings on the surface of a shallow central cavity, as shown in the section, *fig.* 2, *Lign.* 73. The characters of this genus are well exemplified in a common species of the Greensand (*S. pyriformis, Lign.* 73), described by the late Mr. Webster, from specimens collected in the Isle of Wight, where it occurs in profusion, near Ventnor, and the Western lines. This zoophyte is pyriform, (*Lign.* 73, *fig.* 1,) and has a shallow cylindrical cavity, supported upon a long slender stem, the base of which is fixed by root-like processes (*fig.* 5); the transverse fracture shows a section of the longitudinal tubes. This species has been found in numerous localities of the Greensand, and also in the Firestone or malm-rock.†

The Portland limestone contains numerous remains of a

* The pebbles represented in Pict. Atlas, pl. xlv. fig. 5, 12, are specimens of this kind.

† Dr. Fitton's figures, Geol. Trans. vol. ii. pl. xv.*a*, are very beautiful and accurate.

Siphonia closely resembling this species; and varied sections of its stems produce the white markings commonly observable on the slabs of pavements.



LIGN. 73. SIPHONIÆ, FROM THE GREENSAND; *nat.* *Wilts, and Isle of Wight.*

Fig. 1.—SIPHONIA PYRIFORMIS; the body or upper part.
2.—Vertical section of the same, showing the internal structure, and the central cavity.
3.—Specimen of S. PYRIFORMIS in a young state.
4.—SIPHONIA (*Polypothecia*, of Miss Benett,) LOBATA; *Firestone or Upper Greensand, Warminster.*
5.—The lower part of the stem, and radicles, of S. PYRIFORMIS.

A group of Sponges from the Upper Greensand, near Warminster, figured and described by the late Miss Etheldred Benett,* under the name of *Polypothecia*, comprises several

* An elegant Memoir on the Wiltshire Fossils, by this accomplished lady, is published in Sir R. C. Hoare's "Wiltshire."

forms that are allied in structure to the Siphoniæ. These fossils present considerable diversity of shape; one of the lobed forms is delineated in *Lign.* 73, *fig.* 4: and a branched species in *Lign.* 74. Upon breaking the stem of one of these zoophytes transversely, sections of parallel longitudinal tubes like those in the Siphoniæ are exhibited.

LIGN. 74.
POLYPOTHECIA DICHOTOMA.
Upper Greensand, Warminster, Wilts.

The Kentish rag contains irregular ramose spongeous bodies, which belong to this group of porifera; and Mr. Bensted has discovered in his quarry, near Maidstone, numerous remains of a polymorphous lobed zoophyte, having a porous structure beset with spicula. In the Firestone of Southbourn, Steyning, and Bignor, in Sussex, I have observed large pyriform and subcylindrical Siphoniæ.

The organization of all these zoophytes was evidently adapted for the imbibition and circulation of sea-water, in a more perfect and definite manner than in the irregular simple sponges.

Flint-pebbles inclosing remains of Siphoniæ abound on the Sussex coast, especially in the shingle near Brighton, having been washed out of the chalk cliffs. There were several chalk-pits in Edward-street, (now, I believe, filled up and the area built upon,) in which every flint enveloped a sponge or siphonia; many specimens were mineralized by pyrites and beautifully exhibited the internal structure of the originals.

Siphonia Morrisiana. *Lign.* 69, *fig.* 3.—A polished slice of a pebble from Brighton, whose markings are derived from the transverse section of an undescribed zoophyte is figured, *ante*, p. 224: though scarcely more than half the diameter of the original is preserved, yet its structure is well shown; the centre is occupied by numerous parallel openings, the sections of longitudinal tubes, and is surrounded by a broad zone of spongeous tissue.

I have seen many examples of this beautiful fossil, set for brooches in the jewellers' shops in the Isle of Wight, and at Brighton.*

Siphoniæ (chiefly *S. pyriformis*) are abundant in the Upper Greensand, near Farnham in Surrey, but their tissues are saturated with phosphate of lime, instead of silica as is ordinarily the case; the entire sponge usually contains between 50 and 60 per cent. of phosphate: hence these fossils have, of late, been in great request for manure.†

Choanites Königi, *Lign.* 75.—The zoophyte which has given rise to the fossils I have distinguished by the name of *Choanites*,‡ is of a spheroidal or subovate form, and appears to have been composed of a softer tissue than the ordinary sponges. It has a central cavity, and was fixed at the base by long rootlets: its mass is traversed by numerous tubes or channels, which open on the inner surface of the cavity; it differs from Siphonia in not having a stem composed of

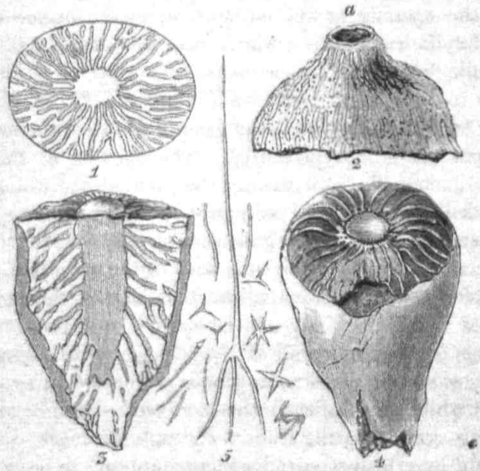
* The specific name is in honour of John Morris, Esq. F.G.S. the author of the "Catalogue of British Fossils," whose important services to Palæontology and Geology it is gratifying thus to acknowledge.

There are coloured figures of Siphoniæ in Pictorial Atlas, pl. xxxix. fig. 9; pl. xlii. fig. 3, 4, 5, 7, 12, and 13; pl. xliii. fig. 6.

† Mr. Payne, of Farnham, a distinguished agriculturist, has largely made use of them, both in the natural state and treated with sulphuric acid. The Firestone strata on St. Catherine's Hill, Isle of Wight, have been dug for a like purpose. See an "Account of the Phosphate Diggings," in my Isle of Wight, Second Edition, p. 448.

‡ Foss. S. D. p. 178.

bundles of tubes, and probably also in its constituent substance. Among the Sussex and Wiltshire chalk-flints specimens of this zoophyte are very common; they are easily recognized by the peculiar markings produced by the silicified tubes that radiate from the centre, as seen in *Lign.* 75, *fig.* 4.



LIGN. 75. CHOANITES KÖNIGI. (G. A. M.)
Chalk, Lewes.

Fig. 1.—Transverse section of a siliceous specimen.
2.—Upper portion of a *Choanite*, in chalk, showing the opening of the central cavity at *a*.
3.—Vertical section of a *Choanite*, in flint, exposing a section of the mass, and canals passing obliquely from the central cavity, through the substance.
4.—*Choanite* in flint; the usual appearance of these fossils.
5.—Various kinds of SPICULA of fossil sponges; *magnified*.

The semi-diaphanous pebbles on the Sussex coast, more frequently contain Choanites than any other zoophytes. From the beautiful and varied markings observable in the polished sections, they are in great request for brooches, and are termed *petrified sea-animal flowers** by the lapidaries; among

* From the supposition that the original was an *Actinia*, or *Sea-Anemone.* A coloured vertical section of a pebble of this kind is

the shingle on the sea-shore at Bognor, Worthing, and other places, very fine examples may be collected.

Lign. 75, *fig.* 4, represents the usual appearance of a flint deriving its form from a Choanite; *fig.* 2, is the upper part of a Choanite preserved in chalk, and richly coloured by iron; the opening at the summit, *a*, is the orifice of the central cylindrical cavity, which is in this instance filled up by chalk, but in flint specimens, with silex of a different colour to that of the surrounding mass. If *fig.* 2, were placed on the top of *fig.* 4, the general shape of the original zoophyte would be represented. The opening at the base of *fig.* 4, marks the spot whence the processes of attachment proceeded. The vertical section of a flint, similar to *fig.* 4, is shown at *fig.* 3; and in this example are seen the central cavity, and a section of the substance of the zoophyte, which is traversed by numerous tubes, that ramify through the mass of which the body was composed, and terminate in openings on the inner wall of the central cavity, or sac. A transverse section of a similar flint is delineated in *fig.* 1; the central white spot indicates the sac filled with flint, and the tubes are seen radiating from it through the mass; under a powerful lens the interstitial structure appears to be granular rather than porous. The perfect transparency of the body when silicified, and the rich tints it has acquired from metallic solutions, and the compressed state in which it is often found, seem to indicate that the original mass was a soft gelatinous substance, like that of the *Actinia*, strengthened by spicula; for numerous tri-radiate spines, like those on the left-hand of *fig.* 5, *Lign.* 75, occur occasionally in chalk specimens.

In many Choanites, which differ in no other respect from the present species, vertical sections show on each side the

figured in my "Thoughts on a Pebble," Eighth Edition, pl. ii. See coloured figures of Choanites in Pict. Atlas, pl. xlii. fig. 1, 9, and 10; pl. xliv. fig. 8; and pl. xlv. fig. 10.

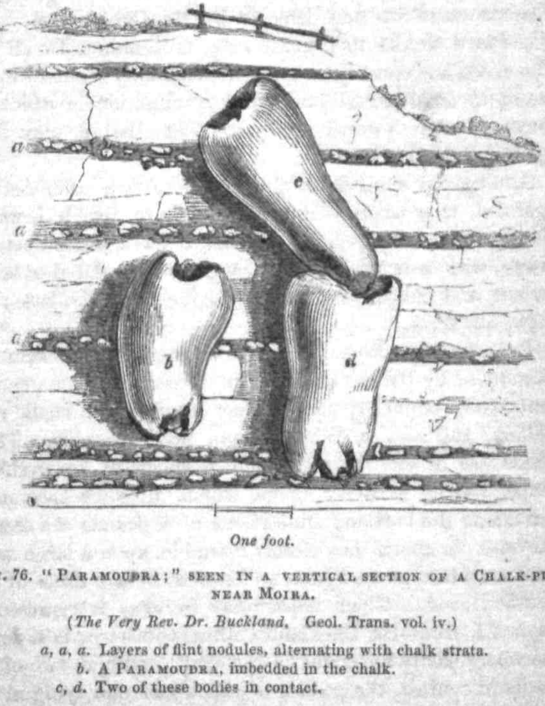
central cavity, large oval spots, that are sections of a canal which traverses the entire mass, proceeding from the base to the summit, in a spiral coil around the central cavity. This structure was first detected by Mr. Cunnington. Mr. Woodward thinks this spiral tube is common to all the Choanites, and constitutes a generic character; but so many examples have passed under my examination in which no traces of such a canal are perceptible, that it may be a specific difference.

Among the chalk amorphozoa whose true affinities are doubtful, is a small turbinated zoophyte, which I would place provisionally under this genus; it has a shallow central cavity, with a broad smooth margin, a reticulated external surface, and radicle processes proceeding from the base; see *Lign.* 80, *fig.* 1.

PARAMOUDRA. *Lign.* 76.—This vernacular Irish term was introduced by Dr. Buckland, in his account of some gigantic flints, thus popularly named, that occur in the chalk near Belfast, and also at Whitlingham, near Norwich. These fossils are of an irregular, oblong, spherical, or pyriform shape, having a cavity above, which, in some specimens, extends to the bottom; indications of a pedicle are seen at the base; in short, they closely resemble, upon a large scale, the funnel-shaped spongites, so frequent in the flints of the South Downs. Their appearance *in situ*, is represented *Lign.* 76, from Dr. Buckland's illustrations: *b*, is a single specimen, partly imbedded in the chalk, and *c*, *d*, two of the fossils in contact, the pedicle of the upper one lying in the cavity of the lower.

These bodies are from one to two or more feet in length, and from six inches to a foot in diameter. The appearance, both of the outer and inner surface, is that of the usual white calcareo-siliceous crust of spongitic chalk-flints. Upon breaking them, no decided structure is perceptible; but here and there, patches of red and blue chalcedony occur, as in

the Ventriculites and spongites in chalk-flints; the originals were probably large goblet-shaped zoophytes, allied to the



One foot.

LIGN. 76. "PARAMOUDRA;" SEEN IN A VERTICAL SECTION OF A CHALK-PIT, NEAR MOIRA.

(*The Very Rev. Dr. Buckland.* Geol. Trans. vol. iv.)

a, a, a. Layers of flint nodules, alternating with chalk strata.
b. A PARAMOUDRA, imbedded in the chalk.
c, d. Two of these bodies in contact.

sponges, but of so perishable a nature as to leave but few traces of their organization, save their general form. Specimens may however yet be found with the structure preserved, for many years elapsed after the first discovery of flint ventriculites, before I obtained examples that threw light on their, origin and formation.

In the Devonian slates of Polperro some curious fossils, supposed to be remains of fishes, have been ascertained by Prof. McCoy to be Amorphozoa, and are described by that eminent palæontologist under the name of *Steganodictyum*.*

CLIONITES (*Morris*) *Lign.* 130.—A recent parasitical sponge (first described by Dr. Grant under the name of *Cliona*), consisting of a fleshy substance, full of siliceous tubular pin-shaped spicula, gives rise to those perforations with which oysters and other shells are often completely riddled.† Certain bivalve shells in the cretaceous seas appear to have been peculiarly obnoxious to the depredations of similar zoophytes, and in consequence of the cavities left by the decay of the sponge having subsequently been filled up by flint, a curious series of fossil bodies has resulted, which we shall more particularly notice hereafter. These fossils Mr. Morris has distinguished by the name *Clionites*, to indicate their origin; they are not, however, the silicified sponge, but inorganic casts, moulded in the excavations. The common species is *C. Conybeari*: "cells irregular, somewhat polygonal, with one or more papillæ; surface finely tuberculated; connecting threads numerous." ‡

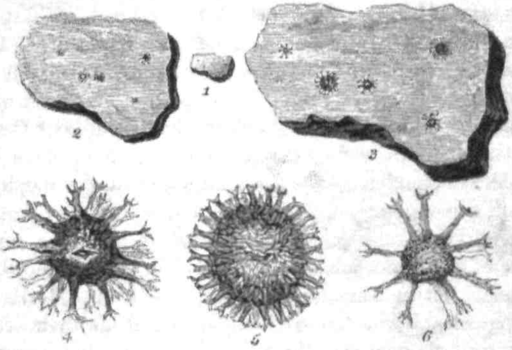
SPICULA, OR SPINES OF PORIFERA. *Lign.* 75.—Siliceous spicules, as we have had occasion to mention, occur in immense quantities in some of those deposits which abound in the remains of spongites. These spines are tubular, and of various shapes; some are acicular, or needle-like; others of a stellate form; many are triradiate or multiradiate; and some have the shape of a trident; a few of these fossils are figured in *Lign.* 75. As the *Actinia*, *Gorgonia*, and *Alcyonia*, possess spicula, some of the fossil spines may have been derived from those zoophytes. The larger spicules may be

* "Synopsis of the Classification of the British Palæozoic Fossils," by Prof. Sedgwick and Fred. McCoy. 4to. Fas. 2, p. vii. pl. 2 A. 1852.

† For an account of the characters of the recent Cliona, see a monograph by Mr. Hancock, Annals of Nat. Hist. May 1851.

‡ Ann. Nat. Hist. August 1851, pl. iv. fig. 8.

discovered with a lens of moderate power, or even by the unassisted eye; but all will amply repay a microscopical examination, and the minutest can only thus be detected.



LIGN. 77. A GROUP OF SPINIFERITES IN FLINT.

(*Seen by transmitted light.*)

Fig. 1.—A thin translucent chip of flint; *nat.*
2.—The same magnified, and viewed by transmitted light; showing a group of five SPINIFERITES.
3.—The same more highly magnified.
4.—SPIN. RAMOSUS; one of the animalculites seen in fig. 3, very highly magnified.
5.—SPIN. REGINALDI; one of the same group; × 300 diameters.
6.—A variety of S. RAMOSUS; another of the same cluster of SPINIFERITES.

SPINIFERITES (*Xanthidium*, Ehrenb.). *Lign.* 77.—I propose to describe in this place those elegant and very minute bodies, that occur in great numbers in the chalk and flint, and which, on the authority of M. Ehrenberg, were regarded as identical with the siliceous frustules of the genus of fresh-water Desmidiæ, named *Xanthidium** (*ante*, p. 91.) Later and more correct observations have proved that the fossils

* Several recent species of Xanthidium are figured in *Plate IV.* of this volume.

under consideration entirely differ from their supposed homologues; their original substance not being siliceous, but flexible and membranous; and that instead of being spores of algæ, they are probably the gemmules either of porifera, or of polypifera.

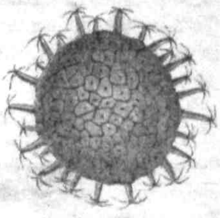
To avoid the perpetuation of the error by the retention of the botanical name of a recent genus of plants, for fossils whose vegetable origin is very problematical, and which are entirely distinct from their supposed analogues, I would substitute that of SPINIFERITES,* a term simply expressive of the general aspect of these bodies; that of a globe or sphere beset with spines. The appearance of these fossils will be understood by the examination of a group discovered by Mr. Reginald Neville Mantell, in a fragment chipped off from a flint pebble; and I will describe the mode by which these minute objects were detected, as it offers a good practical lesson for the young investigator.

The chip of flint is represented, of the natural size, in *Lign.* 77, *fig.* 1; it was immersed in oil of turpentine for a short time, and then placed on a piece of glass, and examined with a moderate power, by transmitted light, the turpentine having rendered the translucent flint almost as transparent as glass; this appearance is shown in *fig.* 2; the organisms here represented are from $\frac{1}{300}$ to $\frac{1}{500}$ of an inch in diameter. The half-inch object-glass was next employed, and *fig.* 3 gives the result. The quarter-inch object-glass, and a corresponding eye-piece, were then substituted, and by the adaptation of a camera lucida, *figs.* 4, 5, and 6, were delineated. As *fig.* 5 proved to be a new species, it was named after its discoverer.

The specimens in flint, when rendered transparent and viewed by transmitted light under a high power, as shown in *Lign.* 78, and 79, appear as hollow globular bodies, beset

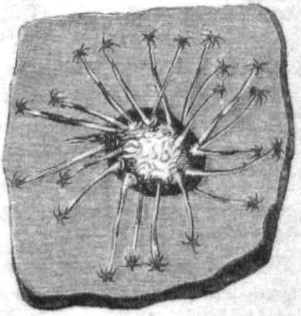
* From *spina*, a spine, and *fero*, to bear.

with spinous processes, which in most species are fimbriated at the extremities. There is considerable variety in the form and length of the spines. In *S. Reginaldi*, these appendages are numerous, regular, short, and relatively thick: in an elegant species discovered by the Rev. J. B. Reade (*Lign.* 79) they are long and palmated: in other kinds they are of intermediate size and proportions.*



LIGN. 78.
SPINIFERITES REGINALDI,
(*Magnified 500 diameters.*)

The apparently torn and collapsed state of the body and arms of some examples first led me to doubt the siliceous nature of the original substance; and on my discovery of the soft parts of foraminifera in flint and chalk, Mr. Deane undertook to search for the so-called Xanthidia in chalk, that these bodies might be subjected to chemical analysis.† Mr. Deane succeeded in detecting all the usual species in the Dover chalk, by digesting some chalk in dilute hydrochloric acid, and mounting the residue in Canada balsam. In this state the shape of the body is that of a depressed sphere; many of the specimens appear to have a circular opening, and the



LIGN. 79.
SPINIFERITES PALMATUS; IN FLINT.
(× 500 *diameters.*)

* Excellent figures of several species are given in a Memoir by H. H. White, Esq. of Clapham, in the Trans. Microscopical Society, vol. i. p. 77.

† A torn and apparently shrunken specimen from chalk, is represented in my paper on Foraminifera; *Philos. Trans.* 1846, p. 465.

arms or spines to be closed at the extremities. Upon pressure under water between two pieces of glass, they were torn asunder as a horny or cartilaginous substance would be, and the spines in contact with the glass were bent. Some after maceration in water several weeks became flaccid ; a proof that they are not siliceous.*

The real nature of these fossils must be regarded as still undetermined : their prevalence in the chalk flints whose forms are derived from zoophytes, seems to countenance the supposition that the Spiniferites are the gemmules or early state of animals of this family ; but I have never detected any organic connexion between them and the porifera with which they are associated ; it is possible they may be the germs of the remarkable zoophytes we have next to examine.

VENTRICULITES.† *Lign.* 80, 81, 82.—At every step of our review of the fossil zoophytes, I find myself embarrassed by the conflicting opinions entertained by naturalists, respecting some of the most abundant of the extinct forms ; arising from the imperfect state of our knowledge as to the structure of the originals, which compels a comparison with recent types, from which, perhaps, the fossils differed essentially in their organization. This remark especially applies to the zoophytes which have given rise to the fungiform flints so well known to the inhabitants of the chalk districts of Sussex, as "*petrified mushrooms*," from their close resemblance in form to fungi : a specimen with this name inscribed on it in the cabinet of a friend first drew my attention to these curious fossils. In *Lign.* 80, *figs.* 2, 3, 4, 6, 7, 8, 9, several flints of this kind are represented ; *figs.* 3, 6, 8, are

* Memoir on Fossil Xanthidia, by Henry Deane, Esq. Microscopical Journal, 1846.

† Ventriculite ; from *ventriculus*, a ventricle or sac.

fungiform ; *fig.* 7, is the upper part of a specimen, the stem having been broken off ; *figs.* 2 and 4, are examples of the lower part of the zoophyte ; in all, there are openings at the base, and a groove on the margin or edge of the upper part in which the structure of the inclosed fossil is visible ; upon breaking these flints, sections of a funnel-shaped body are exposed.

LIGN. 80. FLINTS, DERIVING THEIR FORMS FROM ZOOPHYTES.

From the South Downs, near Lewes ; $\frac{1}{6}$ nat.

Fig. 1.—CHOANITES (?) TURBINATUS.

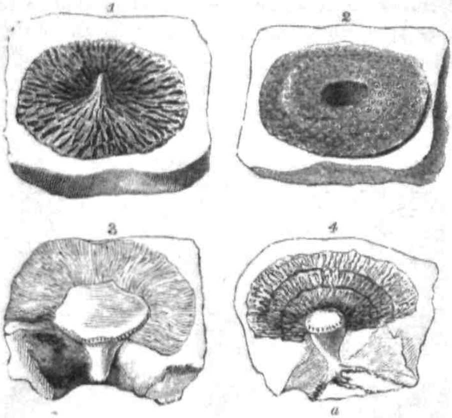
2, 3, 4, 6, 7, 8, 9.—FLINTS, whose forms are derived from VENTRICULITES, provincially called "*petrified mushrooms.*"

5.—SPONGITES LABYRINTHICUS.

10.—SPONGITES FLEXUOSUS.

The origin of these fossils will be understood by reference to the four specimens delineated in *Lign.* 81. In *fig.* 3, a fungiform flint, resembling *fig.* 6, of *Lign.* 80, is seen in the lower part of a cup-shaped zoophyte ; while above, and surrounding the flint, the impression remains of the reticulated outer surface, deeply coloured by a ferruginous tinge. In *fig.* 4, *Lign.* 81, a small turbinated flint, resembling *fig.* 4, of *Lign.* 80, occupies the base, and three rootlets are seen emerging from it at *a*. In *Lign.* 82, *fig.* 1, in which the chalk has been removed so as to expose the outer surface of the Ventriculite, a flint occupies the centre at *c* ; above

which, the radiating reticulated structure is spread out on the chalk, *a*; the base, with its roots, is shown at *b*.



LIGN. 81. VENTRICULITES RADIATUS; ⅚ *nat.*

Chalk; near Lewes.

Fig. 1.—A perfect specimen in chalk, inverted, showing the external reticulated surface; the apex of the base projects in the centre.

2.—Specimen expanded, displaying the inner surface, studded over with the openings of the cells or tubes.

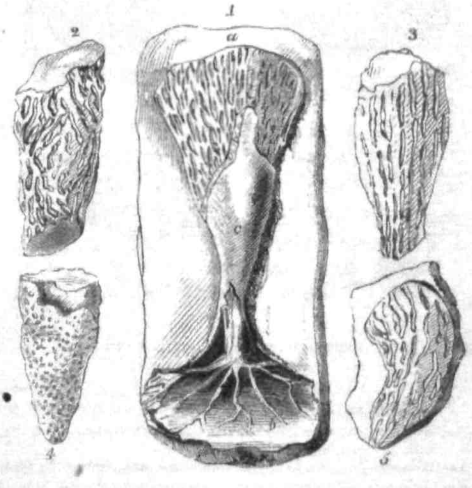
3.—A VENTRICULITE in chalk; the lower part inclosed in flint.

4.—Portion of a VENTRICULITE; the stem towards the base is enveloped in flint, and three radicle processes spread from it into the surrounding chalk at *a*.

These specimens demonstrate that all the flints referred to, have been moulded in the cavities of cyathiform zoophytes; and that their diversity of figure has arisen from the amount of silex that happened to permeate the organism; if but a small proportion of silica in solution was present, then flints, like *fig.* 4, were produced; if the quantity were sufficient to fill up a considerable part of the tissues of the original, fungiform flints, as *Lign.* 80, *fig.* 3, and *Lign.* 81, *fig.* 3, were the result. The disciform flints originated from the ex-

panded examples, *Lign.* 81, *figs.* 1 and 2 : and when the silex was insufficient to silicify the entire zoophyte, an annular flint, resembling a quoit, was formed.

The form of the original was evidently that of a hollow inverted cone, terminating in a point at the base, which was attached by fibrous rootlets to other bodies. The outer



LIGN. 82. PORTIONS OF VENTRICULITES; $\frac{1}{4}$ *nat.*

Chalk, near Lewes.

Fig. 1.—A specimen, in which the middle is inclosed in a flint *c*; the external structure of the Ventriculite is seen at *a*, expanded on the chalk; and the pedicle with its roots is exposed at *b*. The figures are one-fourth the size of the originals.

2, 3, 5.—Chalk specimens, showing the external structure of stems of Ventriculites.

4. A siliceous cast of the cavity of a Ventriculite covered with papillæ, moulded in the orifices of the cells.

integument was reticulated, that is, disposed in meshes, like net-work ; and the inner surface studded with regular openings, apparently the orifices of tubular cells. The substance

of the mass appears to have been sufficiently flexible to expand and contract without laceration. This opinion is based on the fact, that in many specimens the zoophyte is a nearly flat circular disc (*Lign.* 81, *figs.* 1, 2); and in others a subcylindrical pouch. In the former state the outer reticulated structure is elongated, while in the latter, it is corrugated; hence I am led to conclude that the original possessed a common irritability, and was able to contract and expand like many of the flexible polypiaria. The openings on the inner surface are cylindrical, and very regular; the flints often present sharp casts of them, which appear like rows of minute pillars. When the flint filling up the cavity of a Ventriculite can be extracted, it is a solid cone, studded with papillæ, the casts of the cells, as in *Lign.* 82, *fig.* 4.

In the flints, the substance of the Ventriculites is generally as translucent as that of the Choanites, and defined by its rich purple, sienna, or grey colour;* but towards the base and margin it is more or less calcareous; and in many examples the whole, or a large portion of the zoophyte, is in this state. But this fact does not invalidate the inference that the original was flexible; for in these instances the tissues may have been immersed in fluid chalk before their envelopment in flint.† The chalk specimens are commonly as friable and earthy as the surrounding stone, from which they are distinguishable by their ochreous colour.

The stain always observable in the tissues of the chalk Ventriculites and other zoophytes, while the surrounding

* Pict. Atlas, pl. xlv. fig. 9, represents a beautiful transverse section of the lower part of a Ventriculite in flint, richly coloured. Pl. xliii. fig. 16, is a pebble containing the base of a Ventriculite; the orifices on the top have been produced by the transit of the radicle processes; for the fossil is drawn in an inverted position, a common error before the origin of these flints was ascertained.

† A piece of sponge dipped in liquid plaster of Paris, and afterwards inclosed in a transparent substance, as glass, would present such an appearance.

white limestone is uncoloured, may be explained by the chemical changes to which the decomposition of animal matter under such circumstances would give rise. If sulphuretted hydrogen were evolved from the putrifying zoophytes imbedded in calcareous mud containing iron in solution, the sulphur would enter into combination with the iron, the hydrogen escape, and a sulphate or sulphuret of iron be deposited, atom by atom, and thus impart colour and permanence of form to the original.

When the inclosed organisms in the flint nodules have perished, chalcedony, quartz crystals, or crystallized pyrites, sometimes of great beauty, are found occupying the cavities; in short, numerous modifications of the petrifactive process are beautifully exhibited in these common, but highly interesting, cretaceous fossils.

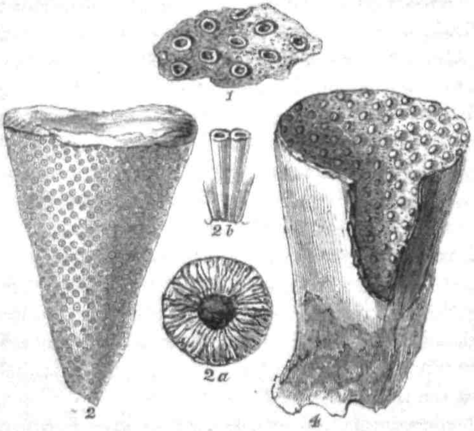
The species to which the previous remarks more immediately refer, is named *Ventriculites radiatus;* from the radiated appearance of the external integument; some of the expanded specimens are more than one foot in diameter.*

VENTRICULITES ALCYONOIDES. *Lign.* 83.—Under the name of "*Ocellaria inclusa*," the late Mr. König† figured and described an elegant fossil zoophyte not uncommon in the chalk and flints of Sussex. This fossil is inversely conical, and somewhat resembles the cast of the cavity of *Ventriculites radiatus*, but a little attention will enable the collector to distinguish it. The flint that is moulded in *V. radiatus*, is surrounded by the substance of the zoophyte, and if found detached, with the investing material removed, shows no struc-

* The reader interested in the history of these objects should consult Foss. South Downs, p. 167, plates x. xi. xii. xiii. xiv. A memoir by the Author on these fossils, under the name of *Alcyonium chonoides*, with four beautiful plates, was published in the Linnæan Transactions, vol. xi. 1821. The *Ventriculites* are the only organic remains figured in Conybeare and Phillips's Geology of England and Wales, p. 76.

† Icones Foss. Sect. fig. 98.

ture whatever, but simply a surface covered with minute papillæ. The present zoophyte is generally included in a nodule, and by a slight blow may be readily separated from



LIGN. 83. VENTRICULITES ALCYONOIDES. *in Flint. Lewes.*
Ocellaria inclusa. König.

Fig. 1.—Portion of the surface of fig. 2, magnified.
2.—The fossil body extracted from the flint, fig. 4.
2*a*.—Tranverse section of the same, showing a central spot of flint, surrounded by tubular cells.
2*b*.—Two of the cells of fig. 2*a*, highly magnified.
4.—The hollow flint, from which fig. 2 was extracted; the papillæ on the surface, are casts of the apertures of cells.

the surrounding flint; it then has the appearance of a white calcareous cone, beset with regular cells, disposed in quincunx order (*Lign.* 83, *fig.* 2); leaving a conical cavity in the flint, which is covered with corresponding eminences (*Lign.* 83, *fig.* 4). Upon breaking the cone itself, it is found to consist of a dense reticulated structure, from one-eighth to a quarter of an inch in thickness (*Lign.* 83, *fig.* 2 *a*), investing a solid nucleus of flint, the surface of the latter being covered with minute points, which are less regular than

those on the cavity of the outer case. The specific name, *inclusa*, was suggested by this character; which, however, is only accidental, for the specimens imbedded in chalk, are simply surrounded by the stone. It is the calcareous nature of the fossil, which renders it so easily separable from the investing flint, while its cells afford numerous points of attachment, and these remain as casts in relief on the interior of the hollow case: I have not observed the same regularity of structure on the inner as on the outer surface.

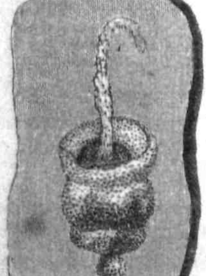
The reticulated integument of this zoophyte resembles in structure that of *V. radiatus*. With regard to the latter, I should state that Mr. Toulmin Smith * discovered that the inosculating fibres of the intimate tissue formed an octahedral plexus at each knot or point of union; and this structure Mr. Smith regards as peculiar to the Ventriculites, and states that he detected it in all the fossils he has arranged under the name *Ventriculidæ*. No spicula have been detected in the integuments.

Until more ample and satisfactory evidence is collected as to the nature of these fossils, the interests of science will be best promoted by allowing the question to remain sub judice, and restricting the term Ventriculites to those zoophytes which possess the general characters of the type to which the name was originally assigned; namely, a vasiform or subcylindrical frame-work, terminating at the base in a point, and fixed by radicle processes; the substance consisting of a plexiform fibrous tissue; externally constituting a reticulated integument, the meshes disposed in a radiating manner from the base to the periphery; the inner surface studded with open cells regularly arranged.

In the former edition of this work the Ventriculites were placed with the Polypifera from the structure of the open-

* "On the Ventriculidæ;" a series of papers published in the Annals of Natural History, with many figures of cretaceous zoophytes, By Toulmin Smith, Esq.

ings or cells, for these are so symmetrical, and disposed with so much regularity, as to present a closer analogy to the polype-cells of a coral, than to the large pores of a sponge. The doubts expressed by many eminent observers as to the correctness of this view, have induced me to insert this notice in the present section; leaving the true affinities of these organisms to be determined by future observers. Possibly we have in these fossils the relics of a tribe of zoophytes of an extinct type, that formed a connecting link between the *porifera* and the *polypifera*; however this may be, I will venture to affirm that no one who had seen the infinitely varied examples of these fossils that I have, would for a moment confound them, as some naturalists have done, with the Scyphiæ, and other simple amorphozoa.



LIGN. 84.
A CORAL-POLYPE IN FLINT.
× 500 *diameters.*
(*Seen by transmitted light.*)

POLYPE IN FLINT. *Lign.* 84.—I will here notice an exceedingly minute and interesting object, discovered by the Rev. J. B. Reade, in a flint containing vestiges of a Ventriculite, and which may possibly belong to this tribe of zoophytes. It must however be remarked, that there was nothing to show the collocation was not accidental. The drawing with which Mr. Reade favoured me, is engraved *Lign.* 84. This object is unmistakeably a polype-cell, with some of the integument of the animal protruding, in the form of a shrivelled tube. The possibility of soft animal tissues being preserved in flint, will not now admit of question, as we shall show when treating of the Foraminifera. The record of this fact may lead to the discovery of other fossils of a like nature.

As we proceed in our investigations, the impossibility of rigidly adhering to a zoological classification based on the structure of organs, of which but few, if any, traces exist in the mineral kingdom, becomes more and more apparent; the durable skeletons or polyparia being the only materials from which the palæontologist can gather information, relating to the physiology of the extinct coral-animals which swarmed in the ancient seas, and whose petrified remains constitute a large proportion of the secondary and palæozoic calcareous rocks.

Numerous fossil genera have been established by various authors from the external form of the polyparium, or the disposition and structure of the cells; but a slight attention to this department of palæontology will disclose corals which differ essentially from the typical forms, and new genera and species will require to be added to the already extended catalogue. The few genera selected for the present work, will convey a general idea of the nature of this class of fossils. To ascertain the names of the species he may collect, the student must refer to works especially devoted to the illustration of the corals of particular rocks; as for example, those of the British *Cretaceous* deposits in the monographs of the Palæontological Society; of the *Palæozoic* in *Sil. Syst.*; and in Prof. Sedgwick's Synopsis of the Classification of the Brit. Pal. Foss.; of the *Mountain Limestone* in Prof. Phillips's work; and those of Ireland in Col. Portlock's Geological Memoirs. Those of the palæozoic rocks of New York, are illustrated in Prof. James Hall's splendid work on the Geology of that State.

The fossil zoophytes included in this section present innumerable varieties of form and structure, but agree in the

important character of having originated, (with but few exceptions,) from aggregations of those minute beings termed POLYPES (*many-feet* *). The common *Hydra* (*Wond.* p. 600), or fresh-water polype, that inhabits pools and streams, is a familiar example of a free animal of this kind, consisting of a cellular gelatinous substance, in the form of a short tube, or pouch, surrounded at the upper margin by long tentacula, or feelers, which appear to the naked eye as delicate threads. The *Polypifera*, properly so called, are groups of polypes, permanently united by a common integument or axis, each animalcule having an independent existence. A common support or endo-skeleton, termed *polyparium*,† is secreted by the integuments, which varies in its nature from a mere gelatinous, or horny material, to an earthy, calcareous, and even siliceous substance, that remains when the polypes die, and their soft parts have perished. All the varieties of corals, &c. are nothing more than the durable structures of aggregated masses of such beings.

It may here be necessary to notice a prevailing error, regarding the mode in which the substance called coral is produced. It is very generally supposed that Corals, particularly those bearing stars and cells, have been constructed by animalcules, in the same manner as is the honey-comb, by the Bee; and the expressions often employed by naturalists, of "the coral animalcules building up their rocky habitations," and "constructing their cells," have contributed

* A name derived from the tentacula, or processes, which in some species serve for prehension, and in others for respiration.

† The basis, framework, or endo-skeleton, of these groups of animalcules is termed the *polyparium*, or *polypidom* (polype-habitation); those of a stony hardness are familiarly known as *corals*; these names, therefore, refer to the durable substance, and not to the animals themselves; but in familiar writing, the term *Coral* is often used to designate the entire living mass. The Red-Coral forms a distinct genus called *Corallium*. In fossils, the *polyparium* alone remains, except in very rare instances.

to foster this error. But the processes are in no respect similar: the insect, under the guidance of an unerring instinct, resulting from its peculiar organization, *constructs* its cells; but the polype is incapable of forming, or even modifying, its support or cell in the slightest degree. The polypidom is *secreted* by the animal tissues, in the same manner as are the bones in the vertebrated animals, without the individual being conscious of the process. If a piece of white coral be immersed in dilute hydrochloric acid, the calcareous part is dissolved, and the secreting membrane, in the form of a flocculent substance, is seen attached to the undissolved part; even in some coralline marbles of incalculable antiquity, the animal membrane may, in this manner, be detected.*

From the delicate and perishable nature of many of the gelatinous zoophytes, numerous tribes may have inhabited the seas, which deposited the fossiliferous strata, and yet no indications of their existence remain; while, of others, but obscure traces of their structure are likely to be detected.

The Polypifera are separated into two natural groups or classes; viz. the ANTHOZOA (flower-animals), and the BRYOZOA (moss-animals), or POLYZOA.

The Anthozoa are polypes of the most simple type of structure. The body consists of a symmetrical gelatinous sac, capable of contraction and expansion, with one aperture or mouth, which is encircled by tentacula. The Hydra, or fresh-water polype (*Wond.* p. 600), is a familiar example of a single, locomotive, anthozoan animal. In the compound or aggregated forms, the body is either inclosed in a horny sheath (ex. *Sertularia, Wond.* p. 615), or is supported by a lamellated calcareous endo-skeleton (ex. *Fungia, Wond.* p. 623, pl. vi. fig. 15), or the soft parts invest a stony axis (ex. *Madrepora, Wond.* p. 620), or a horny flexible framework (ex. *Gorgonia, Wond.* p. 616).

The Anthozoa are subdivided into three orders, which are

* See Pict. Atlas, pl. xxxiv. fig. 2.

based on the peculiar characters of the polypes; the *Hydra*, the *Actinia* (Sea-Anemone, *Wond.* p. 622), and the *Alcyonium* (Dead-men's fingers, *Wond.* pl. v. fig. 10), being respectively the type of 1. the *Hydroida*, or Hydraform; 2. the *Asteroida* or Alcyonian; and 3. the *Helianthoida*, or Actiniform zoophytes.

In the Hydroida the body in the compound species is implanted in a horny tubular sheath, and the polypidoms form branched corallines, which are fixed by the base to rocks, sea-weeds, shells, &c.

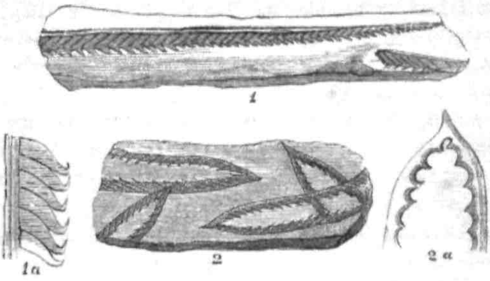
The Asteroida have a horny or calcareous axis, surrounded and inclosed by the soft parts which secrete it.

The Helianthoids, except in the simple free species, as the Actinia, have a lamellated calcareous polypidom, the plates of which radiate from a centre.

The calcareous secretions of the Anthozoa, especially of the Helianthoida, in a great measure constitute the mass of the coral-reefs and coral-islands of tropical seas. Their polypidoms, whether external or internal, maintain but little organic connexion with the compound soft substance. These zoophytes increase by gemmation or budding; some throw up germs from the disk, as in Astreadæ; others laterally, as in Caryophillidæ; and some spirally along the stem, as in Madreporidæ; examples of these modes of reproduction are often found in fossil corals. The increase of coral-rocks is produced by the continual formation of new masses, by the successive generations which spring up as it were from the bodies of their parents; layer upon layer, and tier upon tier, of Helianthoid polypidoms, are found to compose many of the coralline limestones of the palæozoic formations.

Fossil Anthozoa.—The first group of extinct corals to be noticed under this head is the *Graptolitidæ*, a family restricted to the Silurian rocks, and whose natural affinities have been much questioned; some palæontologists referring

them to the *Pennatulidæ*, or Sea-pens, others to the *Sertulariadæ*.*



LIGN. 85. GRAPTOLITES IN WENLOCK LIMESTONE.
(*Murch. Sil. Syst.*)
Fig. 1.—GRAPTOLITES LUDENSIS.†
1*a*.—Magnified view of a portion of the same.
2.—GRAPTOLITES MURCHISONI.
2*a*.—Magnified portion of fig. 2.

GRAPTOLITES. *Lign.* 85.—These curious zoophytes abound in many of the Silurian deposits; they consist of sessile polype cells, arranged in one or two rows to a flexible stem, like the recent Sertularia, or Virgularia. Prof. McCoy refers them to the order Hydroida.

In a recent state these bodies were probably covered with a soft, or albuminous mass, studded with polype-cells, disposed in rows along the margins of the lateral, curved, grapple-like processes, as in the zoophytes termed *Virgularia*,‡ to which one kind bears a great analogy. If two specimens of the *Graptolites Ludensis* be placed together, so that the elongated smooth edges be in apposition, the united stems will be seen to offer a general resemblance to the axis of *Virgularia mirabilis*.

* For a full consideration of this subject, refer to Prof. McCoy's Brit. Palæozoic Fossils.

† *Ludensis*, from Ludlow—to indicate the habitat of the fossils.

‡ See British Zoophytes, pl. xxiv.

M. Barrande divides the Graptolites into three groups or genera, which are defined as follow:—

Graptolites (proper), a single series of cells united together at the base, and adhering along the sides nearly to the orifice of each cell, as in fig. 1*a*. *Monoprion* of M. Barrande.

Rastrites.—The axis reduced to a mere line, on which the cells are placed at relatively wide intervals, and but slightly inclined. These two genera are supposed to have been hydroid zoophytes, and related to the Sertularidæ.

Diprion (*Diplograpsus* of Mr. McCoy), cells in two series arranged along a central axis; these forms present a foliaceous appearance; they are presumed to resemble the existing genera Pennatula and Virgularia.

Graptolites have been found in strata of the same age in Norway, Sweden, and Scotland.* I have received slates literally covered with them, from the Silurian rocks of the United States, by the kindness of my friend, Benjamin Silliman, jun. Esq.

Sir R. Murchison remarks, that the nature of the strata in which these remains occur in Radnorshire, indicates a condition of the sea, well suited to the habits of the family of Pennatulidæ, or Sea-pens; for the recent species live in mud and slimy sediment, and the fossils are imbedded in a finely levigated *mud-stone*, which, from its structure, must have been tranquilly deposited.

I will next describe the single lamellated Anthozoa, and afterwards notice those corals which consist of an aggregation of radiated cells, either frondescent, or disposed in solid masses.

FUNGIA (*Wond.* p. 623).—The corals thus named, from their supposed resemblance to fungi, are of a depressed form,

* Many species of Graptolites from the Lower Silurian rocks of the South of Scotland, are described and figured by Mr. Harkness in Geol. Journal for 1850, vol. vii. p. 58, pl. 1.

and have the under surface scabrous; they are divided above by numerous lamellæ, or plates, which radiate from a central, oblong depression.

When living, the solid stony polyparium is enclosed in the gelatinous mass by which it was secreted, and there are numerous tentacula around the central cavity, or sac. These zoophytes may be compared to the *Actiniæ*, or Sea-Anemones, from which they differ only in having a calcareous axis, while the Actiniæ have a tough albuminous integument. (*Wond.* pl. vi. *fig.* 15, represents the living animal; and *Lign.* 141, *fig.* 2, p. 641, and *Lign.* 58, *fig.* 4, two fossil species).*

ANTHOPHYLLUM ATLANTICUM. *Lign.* 88. *fig.* 4.—In the arenaceous strata of the United States, which the researches of Dr. Morton, of Philadelphia, have proved to be the equivalents of the European Cretaceous formation, a single lamellated coral is not uncommon. It is evidently related to the Fungiæ, and has been named as above by Dr. Morton.

TURBINOLIA KÖNIGI (*Wond.* p. 320).—Polyparium turbinated, striated externally, detached, base not adhering; cell single, radiated.

This genus occurs in all the fossiliferous deposits: a small, well-marked species is frequently met with in the Galt, of which subdivision of the cretaceous strata it is a characteristic fossil. It is figured *Wond. Lign.* 58, *figs.* 1, 2.†

CARYOPHYLLIA CENTRALIS (*Lign.* 89 *figs.* 1, 2: *Lign.* 88, *fig.* 5.—Polyparium turbinated, or cylindrical, simple or branched, longitudinally striated, fixed by the base; cells lamellated.‡

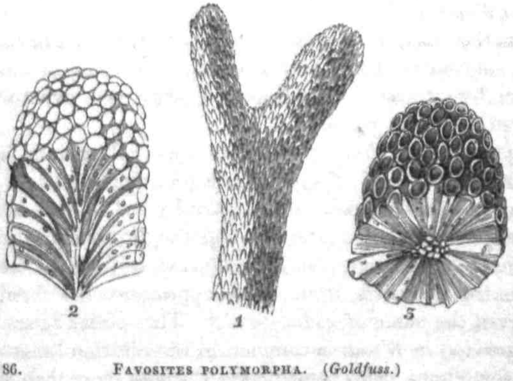
A small recent species (*C. cyathus*), is very common in the Mediterranean, and frequently seen in collections: it is

* Fungia numismalis. Pict. Atlas, pl. xxxvi. fig. 6.
——— polymorpha. Ibid. pl. xliii. fig. 1—4; pl. xlv. fig. 11.
† Turbinolia complanata. Ibid. pl. xxxvi. fig. 9.
——— mitrata. Ibid. pl. xxxvi. fig. 10.
‡ Monocarya (of Lonsdale), Dixon's Fossils, p. 244.

cyathiform, and the base by which it is attached to other bodies, is broad and spreading; the newer tertiary deposits of Sicily contain this species in abundance.

A Caryophyllia, bearing a general resemblance to this species, is common in the chalk, and occurs in beautiful preservation (*Wond. Lign.* 58, *fig.* 3).*

Branched Caryophylliæ are found in the Coralline Oolite and Dudley Limestones (*Sil. Syst.* pl. xvi.) A large proportion of the Coral-rag of the Middle Oolite is composed of a branched species (*C. annularis*) of this genus; *Lign.* 88, *fig.* 5, represents a specimen from near Faringdon.



LIGN. 86. FAVOSITES POLYMORPHA. (*Goldfuss.*)

Devonian limestone. Eifel.

Fig. 1.—Portion of a branch of the coral; *nat.*

2.—Fragment, slightly magnified, with part of the surface broken away below, exposing the central axis, and radiated arrangement of the cells, with their lateral pores.

3.—Another portion, magnified, showing the polype-cells hollow.

FAVOSITES POLYMORPHA. *Lign.* 86. *Lign.* 88, *fig.* 3.—Polyparium stony, polymorphous, solid internally, compact,

* C. centralis, Pict. Atlas, pl. xxxvi. figs. 15, 16.
C. annularis, ibid. pl. xxxvii. fig. 5.

composed of a congeries of diverging or ascending parallel, contiguous, prismatic tubes, covered by pores, divided by lamellæ, and communicating by lateral foramina.

The corals of this extinct genus abounded in the Silurian and Devonian seas; the remains occur with those of other fossil zoophytes of that epoch in great numbers, both in Europe and North America. I have many beautiful examples from the Silurian rocks of the Ohio and Niagara, by favour of Dr. Owen, of New Harmony, and Dr. Yandell, of Louisville, in which the cells are filled up with calcareous spar. The varied markings on many of the Babbicombe marbles, and Torquay pebbles, are derived from the enclosed Favosites (*Wond.* p. 643).

Another species (*Favosites Gothlandica*) occurs in masses of a subconical shape, and is common in some of the Silurian limestones. A fragment, to show the structure, is figured *Lign.* 88, *fig.* 3.

Catenipora (*Wond.* p. 644, *fig.* 3).—Polyparium hemispherical, composed of vertical anastomosing lamellæ; cells tubular, oval, terminal, united laterally. The oval form of the cells when united laterally, and the flexuous disposition of the lamellæ, give rise in transverse sections to elegant catenated markings, from which appearance the fossil has received the name of *chain-coral.** The species figured (*C. escharoides*) in *Wond.* is common in the Silurian limestones, and sometimes forms hemispherical masses more than a foot in diameter. The chain-coral is extensively distributed through the Silurian rocks of the United States. Coloured figures of this exquisitely beautiful coral are given in *Pict. Atlas*, pl. xxxv.

Syringopora ramulosa. *Lign.* 88, *fig.* 2. (*Wond.* p. 641.) These corals bear a general resemblance to the Organ-pipe Coral of Australia. The polypidom is composed of long, cylindrical, vertical tubes, distant from each other, and con-

* Org. Rem. vol. ii. pl. iii. figs. 4, 5, 6.

nected by transverse tubular processes; the cells are deep and radiated by numerous lamellæ.

The external aspect of these fossils is that of a cluster of cylindrical pipes, more or less parallel, connected by short transverse branches. They are the *Tubiporites* of Mr. Parkinson, who has given admirable figures of several specimens.* In these fossil corals that excellent observer first detected the animal membrane. A slab of marble, whose markings are produced by the section of the inclosed tubes of a Syringopora, is represented, *Wond.* p. 644, *fig.* 2. The Mountain limestones of Derbyshire, and of Clifton, on the banks of the Avon, contain figured marbles of this kind, which are manufactured into vases, tables, &c. The genus is extinct.

LITHOSTROTION COLUMNARIA (*Wond.* p. 641, *fig.* 8).—Polyparium massive, solid, composed of aggregated, contiguous, parallel, prismatic tubes, each terminated by a star: cells shallow, multi-radiate, stelliform.

Species of this extinct genus are common in the mountain limestone, in large masses, which, from the pentagonal form, and parallel arrangement of the tubes, appear like clusters of miniature basaltic columns.†

CYATHOPHYLLUM. *Lign.* 87, *figs.* 1, 2. (*Wond.* p. 641, *figs.* 1, 3.)—Polyparium turbinated, simple or compound, internal structure transversely chambered or lamellated; cells polygonal, radiated, depressed in the centre.

The corals of this genus are so abundant in the Silurian rocks, that the seas of that epoch must have swarmed with them. The simple turbinated forms are often several inches long, and being somewhat curved, have obtained the popular name of "*petrified rams'-horns.*"

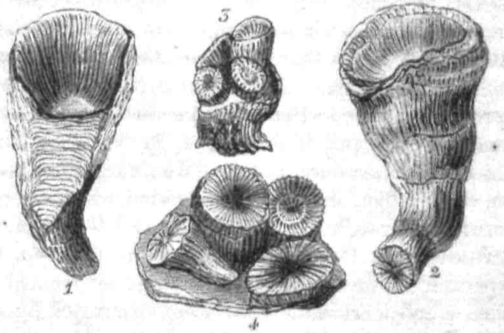
Upon slitting one of these corals vertically, as in *Lign.* 87, *fig.* 1, the axis of the polyparium, beneath the cell, is found

* Pict. Atlas, pl. xxxv. fig. 1. Syringopora geniculata, Pict. Atlas, pl. xxxiv.

† Lithostrotion striatum, Pict. Atlas, pl. xxxvii. figs. 5, 6.

to consist of thin transverse partitions, constituting a series of chambers.

In the compound Cyathophylla, the germs of young cells, occupying the disc of a parent cell, are often met with.



LIGN. 87. CORALS FROM THE DUDLEY LIMESTONE.
(*Sil. Syst.*)

Fig. 1.—CYATHOPHYLLUM TURBINATUM: an oblique longitudinal section, showing at *a* the transverse lamellæ, or cells, of the internal structure.
2.—The same species.
3.—CYATHOPHYLLUM DIANTHUS: a specimen, with four young germs arising from the disc below.
4.—The same species, with four adult cells.

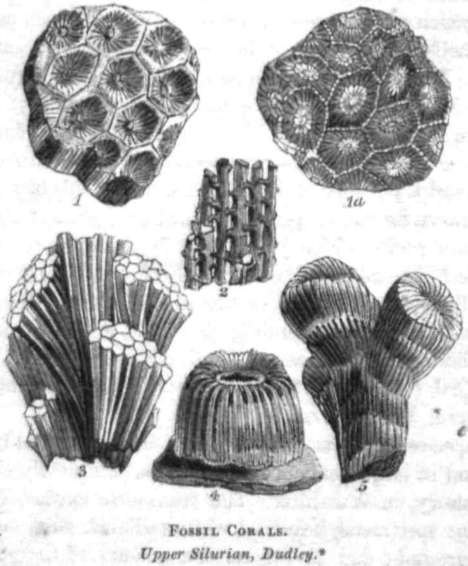
Fig. 3 represents a group of four germs on the parent cell, of *C. dianthus*, a common and beautiful coral of the Dudley limestone.

These corals are also prevalent in South Devonshire, and many of the elegant marbles of Babbicombe are figured by the sections of these polyparia.*

Associated with the Cyathophylla in the Silurian rocks, are certain corals that attain considerable magnitude, and which are principally distinguishable by their internal structure. Such are *Cystiphyllum*, constructed of bladder-like

* Cyathophyllum turbinatum, Pict. Atlas, pl. xxxvi.
——— fungites, ibid. pl. xxxviii.

cells, and *Strombodes*, composed of spirally contorted lamellæ, or plates (*Sil. Syst.* pl. 16bis, *fig.* 4). Other hemispherical masses, presenting on the surface concentric wrinkles, with very minute pores, are common at Dudley, and belong to the genus *Stromatopora*.



LIGN. 88. FOSSIL CORALS.

*Upper Silurian, Dudley.**

Fig. 1.—ASTREA ANANAS.
1*a*.—A polished slice of Marble, formed of ASTREA PENTAGONA. *Devonian.* Torquay.
2.—SYRINGOPORA RAMULOSA. *Mt. L. Derbyshire.*
3.—A Fragment of FAVOSITES GOTHLANDICA. *Ohio.* (*By Dr. Owen.*)
4.—ANTHOPHYLLUM ATLANTICUM. *Cret. U. States.* (*By Dr. Morton.*)
5.—CARYOPHYLLIA ANNULARIS. *Oolite. Faringdon.*

ASTREA. *Lign.* 88, *figs.* 1, 1*a*.—Polyparium massive, irregular in shape, generally globular, formed by an aggregation of lamellated, radiated, shallow, polymorphous cells.

* Figured in Pict. Atlas, pl. xxxvii. fig. 1.

The corals of this genus are very numerous in the seas of the Tropics, and there are many species in the Oolite, and older secondary formations. The Astreæ, Caryophylliæ, Cyathophylla, &c., form the principal mass of the coralline limestones of the Oolite, termed the *Coral-rag,* from the abundance of these relics : being literally composed of an aggregation of large corals, the interstices of which are filled with shells, radiaria, &c., either whole, or in a comminuted state. The heaps of this limestone placed by the road-side, in the N. W. of Berkshire, appear like fragments of an old coral-reef, and attract the notice even of the most incurious observer. I have figured a specimen of Astrea, *Lign.* 88, *fig.* 1, and a polished section, *fig.* 1*a*, from Clifton, a locality well known for the stupendous mural precipices of mountain limestone rocks, which yield beautiful examples of coralline marble.* The mode of increase of the Astrea is very curious ; a subdivision takes place in the old cells, after the manner of the Infusoria ; and among the fossils, a star or cell may often be seen in progress of division into two, three, or four stars (*Sil. Syst.* pl. xvi. fig. 6). A living polype of this genus is figured, *Wond.* pl. vi. fig. 13.

A species of Astrea (*A. Tisburiensis. Wond.* p. 641, *fig.* 9), is found in large hemispherical masses, completely silicified, at Tisbury, in Wiltshire. The transverse surface displays, in some specimens, beautiful white radiated stars, on a dark blue ground ; and in others, the colours of the stars and ground are reversed. This silicified coral is obtained from a bed of chert, a foot in thickness, which is interstratified with the Portland limestone, this division of the Oolite being quarried around Tisbury.†

* Astrea arachnoides, Pict. Atlas, pl. xxxviii. fig. 4.
——— undulata, ibid. pl. xxxviii. fig. 10.
——— Tisburiensis ibid. pl. xxxviii. figs. 12, 13.

† See Catalogue of the Organic Remains of Wiltshire, p. iv. by Miss Etheldred Benett. 4to. 1831.

In the tertiary clays at Bracklesham Bay, Sussex, a beautiful small coral of this type (*Siderastrea Websteri*, Dixon's Foss. tab. i. 5), is found attached to flint pebbles.

Several species of this and the following genus, perfectly silicified, are found in the state of pebbles and boulders in the superficial soil of Antigua, and other islands of the West Indies, associated with the fossil palms, described in a former part of this work. Some of these corals are of great beauty, and polished sections exhibit the coralline structure most perfectly.*

MADREPORA.—Polyparium arborescent or frondescent, porous, fixed; cells deep, with twelve rays, prominent, irregularly dispersed on the surface, and accumulated towards the terminations of the coral.

The term madreporite, or fossil madrepore, was formerly applied to all the branched fossil corals with radiated cells, but is now restricted to those which possess the above characters. The recent common species, figured *Wond.* p. 620, will serve to illustrate this genus. The elevated, branched Madrepores, with minute polygonal cells having twelve rays, the lamellæ of which are denticulated, are termed *Porites*, and are frequent in the Silurian strata (*Sil. Syst.*).

MILLEPORA. *Lign.* 89.—Coral ramose; cells very minute, distinct, perpendicular to the surface, giving the interior a finely striated fracture, disposed irregularly.

There are many fossil species of this genus, some of which are of considerable size. A small species from the mountain limestone is figured *Lign.* 89, *fig.* 7.†

LITHODENDRON. *Lign.* 70, *fig.* 3.—Polyparium branched, formed of deep, cylindrical, elongated cells, which are terminal, and radiated, with a prominent central axis.

Large masses of corals of this genus, composed of clusters

* In the "Spongitenkalk," at Nattheim, near Heidenheim, all the corals are replaced by chalcedony.

† Millepora, Pict. Atlas, pl. xl. fig. 6.

of branches, are imbedded in the mountain limestone of Derbyshire, Yorkshire, &c. ; and a few species occur in the Coralline Oolite; their general configuration will be understood by the figure *Lign.* 70, *fig.* 3 ; but in this specimen the margins of the cells are worn off, and do not present the original deeply excavated form.*

There is a remarkable specimen of this coral in the Bristol Institution (of which a portion is now placed in the Museum of Practical Geology, in London), that was discovered by Mr. Samuel Stutchbury,† in a vein of hematitic iron ore. It is a large mass, in which the entire substance of the coral is transmuted into a metallic ore, forming one of the most interesting natural electrotypes I have ever seen. In this instance, a block of Lithodendron must have lain in a vein or fissure of the rock, and its animal membrane have resisted the action o the gaseous emanations, or mineral solutions, while the calcareous polypidom was dissolved, and the metallic matter deposited atom by atom, as in the case of pseudomorphous crystals.

GORGONIA.—Of the flexible anthozoan coral, which from the flabellated form of the polyparium is generally called "Venus's fan," and by naturalists *Gorgonia*, a few fossil species have been discovered and determined. From the friable arenaceous limestone beds of Maestricht, which abound in corals, fine specimens of a delicate species are occasionally procured. *Wond.* p. 320, *fig.* 5, shows the character of this fossil zoophyte.

FOSSIL BRYOZOA.

The second class of Polypifera, the BRYOZOA or *Polyzoa*, are of a much higher order of organization than those which have engaged our attention. The body is not symmetrical,

* Lithodendron fasciculatum, Pict. Atlas, pl. xxxviii. fig. 8.
† Now of Sydney, Australia.

nor capable of contraction and expansion, as in the Anthozoa: it consists of a digestive cavity or sac, which is bent on itself and open at both extremities. The outer integument is either membranaceous or horny; sometimes calcareous. The oral aperture or mouth is surrounded by a circle of tentacula, from eight to twelve or more in number, and these tentacles are clothed with vibratile cilia. (*Wond.* p. 606, the polype of *Flustra pilosa.*)

The polypes in this order never occur singly; they are always united by a common integument, but each enjoys an individual existence. The animal can extend its tentacula and protrude the mouth from the cell, but the rest of the body is incapable of extension or contraction. These polypifera increase by germination. In their organization, they so closely approach the mollusca, that in recent zoological systems they are placed in that class. The ciliated character of their tentacula has also led to their being named *Cilio-branchiata.* But as it is desirable in a work of this elementary nature to avoid conflicting opinions as much as possible, the fossil Bryozoa will be considered as corals, in the general sense of that term.

FLUSTRA (*Sea-mat*). *Lign.* 89, *fig.* 4, 5.—The polyparium is either membranaceous and flexible, calcareous and encrusting, or foliaceous, composed of cells, arranged in juxtaposition, more or less quadrangular, flat, with a distinct border, disposed on a flat surface, or on opposite surfaces, as in the *F. foliacea.*

This is one of the most common genera of the encrusting and frondescent zoophytes. The *Flustra* consists of a cluster, or aggregation of polypes, invisible to the naked eye; under the microscope, the polype is found to be a transparent gelatinous body bent on itself, with a sac or digestive cavity, having two apertures, the external margin of which terminates in eight or ten tentacula, clothed with cilia; the whole is surrounded by a firm wall, constituting a cell, from

which the animal can protrude its tentacula and upper part. (Figures of the living polypes of Flustræ, *Wond.* p. 605, *pl.* vi. *fig.* 6, 7.)

Many species of *Flustræ* occur in the British strata: the encrusting forms are attached to echinites, shells, &c.; the foliaceous are imbedded in chalk, sand, sandstone, &c. In Mr. Morris's *Cat. Brit. Foss.* ten species are enumerated; none of these are from formations below the Chalk. I have selected for illustration a *Flustra* attached to an echinite from Lewes. *Lign.* 89, *fig.* 5, represents a small portion of the natural size; and *fig.* 4, a few cells magnified, to show their form and arrangement. A foliaceous zoophyte, apparently a bryozoon, is abundant in the Sussex and Kentish chalk, and is often disposed in angular folds. It is generally of a ferruginous colour, and, from its friable texture, it is probable the original consisted of a membranous polypidom or calcareous substance; specimens sometimes extend over several square inches of the chalk. It is common in the chalk-pit at Offham, near Lewes.*

Eschara.†—In these zoophytes the polyparium is encrusting or foliaceous, calcareous and brittle; the cells are thickened on their outer margins, and have a small, depressed, round aperture. They are arranged in two series of planes, adhering together, the cells on each surface exactly corresponding.

Species of Escharæ are found either in flints, or attached to echinites, and other bodies; they have the appearance of patches of flustræ, but with a lens may be distinguished by the symmetrical juxtaposition of the cells on the opposite sides of the polyparium.

* In my South Down Fossils, pl. xv. fig. 6, a specimen of this kind is described as a Ventriculite, *V. quadrangularis.* An admirable lignograph of a remarkable example is given by Mr. Toulmin Smith, under the name of *Brachiolites angularis*; it presents ten deep, flat, angular folds, and has radicle and lateral processes; see "On the Ventriculidæ," p. 93.

† So named from a supposed resemblance to an eschar.

Ellen Maria Mantell, ad nat. delt.

LIGN. 89. CORALS FROM THE CHALK AND MOUNTAIN LIMESTONE.

Fig. 1.—CAROPHYLLIA CENTRALIS; *nat.* (G. A. M.) *Cret. Lewes.*
2.—Front view of half the disc of the same.
3.—Two cells of CRISIA JOHNSTONIANA. × ×.
4.—Magnified view of six cells of the Flustra, fig. 5.
5.—A portion of an encrusting Flustra; *nat. Cret. Chichester.*
6.—IDMONEA (DIXONIANA) CRÈTACEA; *nat. Cret. Lewes.*
The figure on the left shows the under surface; that on the right, the upper surface, with a row of polype-cells on each margin: a portion magnified is given fig. 12.
7.—MILLEPORA RHOMBIFERA. × ×. *Mt. L. Ph. Yorks.*
The small figure on the left is of the natural size.
8.—PUSTULOPORA PUSTULOSA. × ×. *Cret. Chichester.*
The small figure on the left, *nat.*
9.—HOMŒSOLEN RAMULOSUS. × ×. *Cret. Dover.*
The left-hand figure, *nat.*
10.—CRISIA (?) JOHNSTONIANA. (G. A. M.) × 250 linear. *S. s. Maidstone.*
10b.—Two cells of the coral, fig. 10, seen in profile. × ×.
11.—HOMŒSOLEN RAMULOSUS; *nat. Cret. Lewes.*
12.—IDMONEA DIXONIANA; a portion of fig. 6. ×.
13.—RETEPORA LAXA. *Mt. L. Ph. Yorks.*
13†.—A portion of the same ×.
14.—IDMONEA COMPTONIANA. × ×. (G. A. M.) *Chalk, Chichester.* (*Mr. Walter Mantell.*)
The small figure on the right is of the natural size.

CRISIA JOHNSTONIANA. *Lign.* 89, *fig.* 3, 10, 10^b.— The minute recent corals thus designated are allied to *Flustra*, but separated from that genus by the cells being disposed in a single series, and united by connecting tubes. I notice this genus to direct attention to a very curious polypidom from the Greensand of Maidstone, presented to me by Mr. Bensted. The specimen is attached to a fragment of shell. The cells, five of which are represented, *fig.* 10, are elliptical, with the aperture above, and towards one extremity; they are united by very slender, hollow filaments: *fig.* 3, two of the cells seen from above × 250 linear; *fig.* 10_b the same seen in profile.* I have named this species *C. Johnstoniana*, as a tribute of respect to the author of the admirable works on British Zoophytes, previously noticed.

The fragmentary relics of numerous minute and elegant corals, constitute a considerable portion of the mass of some of the white chalk strata; several genera of these zoophytes are figured in Mr. Dixon's beautiful work, and described by Mr. Lonsdale. Attached to the surface of shells, &c., and sometimes standing erect in little crannies, or hollows, of the flints, many beautiful corals may often be detected with the aid of a lens. By brushing chalk in cold water, and examining the deposit, the student will probably discover several of the species figured in *Lign.* 89, which we proceed to describe.

RETEPORA (*Lace-Coral*). *Lign.* 89, *fig.* 13.—A very thin calcareous polyparium, disposed like net-work in foliaceous and branching plates; cells opening either on the upper or inner side.

These are an elegant tribe of corals, of which many species occur in the Chalk formation at Maestricht, in the white-chalk of England, in the mountain limestone of Yorkshire,

* I refer this fossil to the genus *Crisia* with some hesitation; perhaps *Hippathoea* would be more correct, but all the described species of the latter are branched.

(*Phil. York.*), and in the Silurian deposits (*Sil. Syst.*). It may be useful to state, that in the description of the fossil retepores, the openings in the net-work are called *fenestrules*—the spaces between the ends, *dissepiments*—and those between the fenestrules, *interstices*. A delicate fossil retepore from the mountain limestone of Yorkshire (*R. flexa*), is figured *Lign.* 89, *fig.* 13.

FENESTRELLA.—Cells very small, indistinct externally, with small prominent openings; polyparium stony, fixed at the base, composed of branches, which inosculate by growth, and form a cup. Numerous delicate corals, formerly arranged as *Reteporæ*, occur in the Silurian rocks, and have been placed in this genus by Mr. Lonsdale. (*Sil. Syst.* p. 677.)

PETALÆPORA* PULCHELLA. *Lign.* 69, *fig.* 1.—This beautiful cretaceous coral is "tubular, free except at the base; framework composed of vertical laminæ, with an intermediate foraminated structure; apertures to the tubular cavities distributed over the surface; exterior varying with age." It has slender round dichotomous branches, and the polyparium when entire must have formed an elegant plexus of coral. A layer an inch thick, full of branches of this zoophyte, is exposed on the face of the chalk cliffs, near Dover; and beautiful masses, several inches square, made up of this coral, Idmonea and Pustulopora, may be obtained. The microscopic specimen figured in *Lign.* 69, was obtained with many other corals by washing chalk with a brush, and examining the detritus deposited.

PUSTULOPORA. *Lign.* 89, *fig.* 8.—Another very common tubular branched coral of the Dover chalk; the tubes are cylindrical, their apertures are arranged in annular or spiral rows, and slightly projecting, giving a pustulous appearance to the stem and branches. Specimens covering a piece of chalk six or eight inches wide, and a foot long, have been discovered. The example figured is a very minute branch.

* Mr. Lonsdale. Dixon's Fossils, p. 285.

HOMŒSOLEN* RAMULOSUS. *Lign.* 89, *figs.* 9, 11.—This delicate branched coral is formed of large and small tubes variously intermingled, both inclined in the same direction, partially visible on the surface, or wholly concealed, limited to one side of the coral; mouths simple tubular extremities; back without pores, composed of a continuous lamina.†

The elegant coral, *fig.* 11, *Lign.* 89, is thus named by Mr. Lonsdale; it resembles his *fig.* 4. The fossil, *fig.* 9, *Lign.* 89, though very different in its branching, and in the surface, which is covered with pores, is evidently identical with *fig.* 3 of Mr. Lonsdale, which he refers to the same species.

IDMONEA, *Lign.* 89, *fig.* 6.—In this elegant coral the polyparium is calcareous, branched, porous; the cells distinct, prominent, arranged in single rows, more or less inclined, on each side a median line on the inner face only. The genus is extinct.

A beautiful species of Idmonea, of which a small branch is figured in *Lign.* 89, abounds in the chalk of Kent and Sussex; it often forms a cluster, two or three inches in circumference. The surface of the stems is covered with minute pores, and the cells are distinct, and placed in single rows; the left-hand figure of *fig.* 6 shows the plain surface, and that on the right, the opposite and inner, each margin of which is garnished with a row of cells; a portion magnified is represented *fig.* 12.‡

* Homœsolen, from ὅμοιος, similar; and σωλὴν, a tube.

† Mr. Lonsdale, in Dixon's Fossils, p. 307, tab. xviii. B. figs. 3, 4, 5.

‡ In the former edition of this work, I named this species *I. Dixoniana*, to commemorate the researches of my late friend, Frederic Dixon, Esq., of Worthing, who had formed an interesting collection of chalk fossils, and announced a work on the "Zoology of the Chalk Formation," to be richly illustrated with figures of many undescribed organic remains. It appears that a species, supposed to be identical, had been previously named by Mr. Milne Edwards, *I. cretacea*. See Dixon's Foss. tab. xviii. A. fig. 5, p. 281. Mr. Lonsdale places it in a new genus, with the name of Desmeopora semicylindrica. It will convey

IDMONEA COMPTONIANA,* *Lign.* 89, *fig.* 14.—This is a very small and remarkable coral; it is dichotomous, cylindrical, with elongated distinct cells, which are disposed in triplets, at regular distinct intervals, on one side of the stem.

We have now described all the fossil corals figured in *Lign.* 89; and have shown what interesting organisms may be detected in a few grains of calcareous earth. It would be easy to give restored figures of the beings whose stony skeletons are the subject of these remarks, from their close resemblance to existing species; every pore and cell might be represented fraught with life; here the agile inmates, with their little arms fully expanded, and in rapid motion; there retreating within their recesses, and devouring the infinitesimal living atoms that constitute their food; or rapidly shrinking up their tentacula upon the approach of danger; even their varied colours might be introduced, and thus the beautiful and highly interesting picture drawn by the imagination, of a group of living zoophytes of the ancient chalk ocean, be presented to the eye.

Although, for convenience, I have selected the above examples principally from the cretaceous strata, the reader must not suppose that other deposits are not equally prolific in these remains. The Coral-rag of the Oolite, many beds of the Mountain limestone, and those of Dudley and Wenlock of the Silurian System, contain myriads of minute polypidoms associated with the coralline masses of which we have already treated. Exquisite figures of the Silurian corals, by Mr. Scharf, are given in *Sil. Syst.* pl. xv. xvi. and described by

some idea to the unscientific reader, of the labour bestowed on this department of palæontology, to learn that the description and identification of but 25 species of minute corals, represented on three plates, occupy ninety pages of close printing in royal 4to. of Mr. Dixon's work.

* This specific name is in honour of the noble and highly respected President of the Royal Society, the Marquess of Northampton. 1844.

Mr. Lonsdale. A slab of the Dudley limestone often has the entire surface studded with minute corals of many species and genera, lying in bold relief, and in an admirable state of preservation.

Verticillipora (*Lign.* 70, *fig.* 4. *Lign.* 72, *fig.* 3).—Cells poriform, arranged in meshes on the surface of convex imbricating plates round a hollow axis, forming a fixed, irregular, subcylindrical polyparium. *Lign.* 70, *fig.* 4, represents a coral often met with in the gravel-pits at Faringdon, (*ante*, p. 228,) which is referred by Mr. Morris to this genus. It is composed of short cylindrical anastomosing tubular branches, emanating from an expanded base, divided internally by transverse parallel plates, covered with exceedingly minute pores or cells, disposed in meshes; the plates surround a hollow axis; the structure is well shown in the figure.

Lunulites. *Lign.* 70.—The polyparium is stony, orbicular, convex above, concave below; concavity radiated; convexity covered with cells, arranged in concentric circles on diverging striæ.

A species of this coral is often found in the chalk: *Lign.* 70, *fig.* 1, represents a specimen from the South Downs, discovered by Mr. Walter Mantell. The natural affinities of this genus are not determined with precision; but I have placed it with the Bryozoa in accordance with the opinion of M. de Blainville. It is an elegant white coral, and easily recognized among the minute organisms of the chalk.

Geological Distribution of Fossil Zoophytes.—Although the geological distribution of fossil zoophytes affords less striking phenomena than that of the vegetable kingdom, yet some interesting reflections are suggested by the facts we have thus cursorily noticed. We find that in the most ancient seas of which any vestiges of their inhabitants remain, these forms of vitality existed, and produced the same physical results as at the present time; giving rise to coral-

reefs, and banks of coral-limestones, and largely contributing to the solid materials of the crust of the globe. Nearly 400 British species are enumerated by Mr. Morris, and the list has subsequently been greatly extended by the labours of Phillips, Portlock, Lonsdale, McCoy, Milne Edwards, and other eminent naturalists.

The Tertiary formations afford numerous species of Caryophylliæ, Flustræ, Escharæ, Spongia, &c.; and the *Crag*, several genera that are as yet but imperfectly determined. The older Tertiary, or Eocene deposits, contain Turbinoliæ, Astreæ, Fungiæ, Meandrinæ, and species of other genera, the recent types of which are inhabitants of tropical seas.

The zoophytes of the British Chalk have been illustrated in detail by Mr. Lonsdale in Dixon's Cretaceous and Tertiary Fossils of the South-East of England; and by Dr. Milne Edwards in the Monographs of the Palæontological Society.

In the Maestricht deposits, lamelliferous corals, as Astreæ, Fungiæ, Meandrinæ, &c. prevail, and may be extracted from the friable arenaceous limestones in a fine state of preservation. In the White Chalk and Greensand of this country, the Spongites and allied genera are abundant, and associated with Caryophylliæ, Astreæ, and many forms of Bryozoa.

But in the cretaceous formation of England, no coral reefs are observable; the zoophytal remains, with but a few local exceptions, occur promiscuously intermingled with the fishes, shells, Radiaria, and other marine exuviæ; although many layers, or thin seams of chalk and marl, are largely composed of the detritus of corals, like the modern deposits of the Bermudas (*Wond.* p. 613). These phenomena are in accordance with the lithological characters of the White Chalk strata, and the nature of its mollusca, both of which indicate a deep sea; and coral-reefs are only formed at moderate

depths. But in regions where the sea was shallow, during the deposition of the cretaceous rocks, beds of coral limestone were produced; and these also contain littoral (*sea-shore*) shells, associated with the usual sponges and zoophytes (*Wond.* p. 613).

In the marine secondary formations antecedent to the cretaceous, namely, the Lias and Oolite, coral-reefs, which appear to have undergone no change save that of elevation from the bottom of the sea, and the consolidation of their materials by mineral infiltrations, demonstrate a condition of the ocean in our latitudes, which is now only met with in the tropics (*Wond.* p. 614).

The limestones of the Carboniferous, Devonian, and Silurian formations, abound in anthozoan corals, and among them are many kinds of Cyathophyllum, Lithododendra, Syringopora, Catenipora, Graptolites, &c., which are characteristic of these deposits.

The Silurian zoophytes are figured in *Sil. Syst.*; and the splendid works on the British Palæozoic Fossils, by Prof. Sedgwick and Prof. McCoy, now in course of publication, contain many admirable figures of new, or but imperfectly known species.

The extensive beds of coralline limestones, which are found in the Silurian strata, wherever they occur,—for the limestones of this system in North America are characterized by the same species of corals as those of England,—seem to indicate that a more equal temperature prevailed throughout the ocean, at that geological epoch, than at the present time, when the geographical distribution of the coral zoophytes is strictly limited by temperature. The reef-forming genera are now confined to waters where the temperature is not below 70°; their most prolific development being 76°. The apparent exception, the occurrence of coral-reefs at the Bermudas, is found to depend upon proximity to the Gulf Stream (*Wond.* p. 614), which brings down the thermal waters of

the tropics, and increases the local temperature of the sea in those localities.*

ON COLLECTING FOSSIL CORALS.—Few instructions are required for the collection of fossil zoophytes; for as the most important characters of the several kinds have been pointed out in the previous descriptions, the student will be able to select illustrative specimens for his cabinet. The minute corals, &c. of the Chalk, and other limestones, are to be obtained by the same process as that directed for the discovery and preservation of the foraminifera, and other microscopic organisms, at the end of the next chapter. The larger examples should be left attached to a piece of chalk, when practicable, and the surrounding stone removed with a knife or graver, so as to expose as much of the fossil as may be required for the display of its characters, without loosening its attachment to the block. When the investing chalk is very hard, frequently pencilling the specimen with vinegar, or dilute hydrochloric acid, will soften the stone, and render its removal easy, by means of a soft brush: when acid is employed, the specimen must afterwards be well rinsed in cold water.†

The zoophytes that are in part flint, and part chalk, as the Ventriculites, (*ante*, p. 244, *Lign.* 81,) can rarely be obtained, except through the quarrymen who have been instructed how to extract them from the rock. The first

* Mr. Deane's splendid and masterly work on Corals, should be studied by those who wish to be acquainted with the present state of this branch of natural history.

† It may be well to caution the collector against employing sulphuric acid (commonly called *oil of vitriol*) for this purpose, for a white insoluble deposit (sulphate of lime) will thus be formed on the specimen, and its appearance irremediably injured. Many of the fossil corals obtained from the chalk of Dover Cliffs, are so saturated with muriate of soda, from long exposure to the spray of the sea, as to be liable to decomposition in the course of a few weeks, and are therefore not worth purchasing of the dealers.

specimen of this kind that came under my notice, I discovered while breaking a mass of chalk, in search of fungiform flints; when, to my great delight, I found the fossil, *Lign.* 81, *fig.* 3, by which at once, and for the first time, was shown the connexion between the chalk specimens, *Lign.* 8, *figs.* 1, 2, and the flints figured in *Lign.* 8, *figs.* 2, 3, 6, 7, 8. Upon showing this fossil to the quarrymen, and exciting their attention by suitable rewards, I obtained the illustrative series now in the British Museum.* Much light would be thrown on the nature of other zoophytes of the chalk that are invested with flint, if due care were taken in the collection of specimens, and they were examined before extracted from the rock. Loose, delicate specimens, whether from the chalk or tertiary strata, should be affixed with strong gum-water to cards, or pieces of thin board, covered with coloured paper.

The Greensand Spongites, Siphoniæ, &c. may often be extracted from the rock tolerably perfect, by a well-directed blow of the hammer; but fragile species should be left attached to a block, and the surrounding stone be carefully chiselled away, so as to expose the most essential characters.

The Faringdon zoophytes are, for the most part, encrusted by an aggregation of minute polyparia, shells, and detritus, which may be partially removed by washing with a stiff brush, and their cavities cleared with a stout penknife, removing the extraneous matter by *chipping*, not by scraping, or the surface will be injured. In this manner the beautiful specimens figured, *ante*, p. 228, were developed.

The Corals in the hard limestones can seldom be chiselled out to advantage; for the most part, polished sections best exhibit the form and structure of the originals.

Weather-worn or water-worn masses of coral limestone often display the structure of the zoophytes of which they are in a great measure composed, in a beautiful state of

* Petrifactions, Room VI. p. 466.

sculpture and relief : the silicified or calcified corals appearing as perfect as if fresh from the sea. The mural rocks of coral limestone at Florence Court, the seat of the Earl of Enniskillen, are in many parts encrusted, as it were, with syringopora and other tubular corals, laid bare uninjured by the long and insensible effect of atmospheric erosion. A beautiful illustration of the old aphorism,—" Aqua cavat lapidem non vi sed sæpe cadendo,"—is afforded by the splendid examples of cateniporæ, fungiæ, caryophillæ, sculptured in alto-relievo on the face of the Silurian rocks over which dash the rapids at the Falls of the Ohio.

The silicified zoophytes of the West Indies, and those from Ava and the Sub-Himalayas, form beautiful subjects for the microscope ; and chips, or sections, should be prepared in the manner recommended for fossil-wood in the same state of mineralization.

BRITISH LOCALITIES.—The gravels and sands of the Crag afford most favourable sites for obtaining tertiary zoophytes.

In the London clay at Bracklesham Bay, a species of Astrea (*A. Websteri*) is often met with attached to flints and pebbles.

In the Greensand of Atherfield, in the Isle of Wight, an elegant coral (*Astrea elegans*) is by no means rare.

The Greensand gravel-pits, near Faringdon, in Berkshire, abound, as already mentioned, (*ante*, p. 228,) in many kinds of sponges, and other porifera ; and the quarries of oolitic limestone in the vicinity of that town, yield the usual corals of the Jurassic formation in great profusion. I know of no locality richer in fossil zoophytes, than Faringdon.*

The quarries of that division of the Oolite called Coral-rag (as in the north-west of Berkshire, Oxfordshire, Gloucestershire, &c.), afford the usual corals of the Oolite.

The Oolite near Bath contains many species, and large masses of a minute coral (*Eunomia radiata*), are abundant.

* See *Excursion*, Part IV. of this work.

At Steeple Ashton, in Wiltshire, numerous oolitic corals may be obtained. The silicified *Astreæ*, of Tisbury, in the same county, deserve particular notice (*ante*, p. 263).

Clifton, near Bristol, and Torquay and Babbicombe, on the Devonshire coast, are celebrated for their coralline marbles and pebbles; and many of the Derbyshire limestones are equally prolific in similar remains. The Devonian marbles are so largely employed for ornamental purposes,—as brooches, tables, and side-boards,—that the figures produced by the sections of the enclosed corals must be familiar to the reader.*

Dudley, Wenlock, and Ludlow, are well known for the abundance and variety of Silurian polyparia.

Other localities of British corals have been mentioned in the course of this review of fossil zoophytes.

* Specimens of these fossil corals, either as objects of natural history, or as ornaments, may be obtained of Mr. Tennant, 149, Strand.

CHAPTER VIII.

FOSSIL STELLERIDÆ; COMPRISING THE CRINOIDEA OR LILY-LIKE ANIMALS; AND THE ASTERIADÆ, OR STARFISHES.

THE RADIATA, or radiated animals, so designated because the parts of which the body is composed are arranged around a common centre or axis, are divided into three sub-classes; namely, 1, the *Polypifera*, whose fossil remains were treated of in the previous chapter; 2. the *Acalepha*, or Jelly-fishes, whose structures are so perishable as to render it improbable that any vestiges of them will be found in a fossil state, though imprints of the general outline of certain kinds may possibly occur;* and, 3, the *Echinodermata*, comprehending under that term the *Stelleridæ*, or Crinoids and Star-fishes, and the *Echinoderms*, properly so called. This sub-class is the subject of the present section; it comprises four orders, viz.

CRINOIDEA, or Lily-like Animals.
ASTERIADÆ, or Star-fishes.
ECHINIDÆ, or Sea-urchins.
HOLOTHURIADÆ, or Sea-slugs.

Vestiges of the Stellerida are among the earliest relics of animal organization hitherto discovered. Many kinds of Crinoidea abound in the Silurian rocks, and one genus of Star-fishes occurs in the same deposits: the Echinidæ first appear in the Devonian formation.

* The impression of an Acaleph resembling an *Æquorea* (a kind of Medusa), is stated by M. Pictet to have been observed in a slab of schistose rock, in Germany.

The Echinodermata possess the radiated type of structure in an eminent degree; especially the Asterioidæ and the Echinidæ, of which the common Star-fish, and Sea-urchin, are familiar examples. The external integument or skin is in many kinds protected by spines, (hence the name Echinoderms or spiny-skin,) and perforated by numerous foramina for the imbibition and transmission of sea-water, and for the protection of minute soft tubular processes (called *pseudopodia*), which constitute organs of adhesion and locomotion.

The first two orders have endo-skeletons, composed of numerous ossicula or little calcareous bones: in the third order, the Echinidæ, the body is inclosed in a calcareous case or shell, formed of numerous plates closely adjusted to each other; in the fourth order, the Sea-slugs, the body has only a tough outer integument without movable spines.

Diversified in form and external appearance as are the Invertebrata thus grouped together, they are naturally related by their organization. The Crinoidea may be regarded as Star-fishes fixed to one spot by a jointed stem; the Star-fishes as free Crinoidea; the Echinidæ as Star-fishes with the rays coalesced and united into a globular or spherical case; and the Holothuriæ, as elongated Sea-urchins, destitute of spines, and without a calcareous envelop.

CRINOIDEA.—The animals of this order are subdivided into families and genera according to the number, form, and arrangement of the plates composing the calcareous case or receptacle, and the structure of the arms and column. In one living family, the *Comatulidæ*, the body is free; and in one fossil genus, the *Marsupite*, the animal is capable of locomotion through the water.

The essential character of the *Crinoidea*,*—so named

* From κρίνον, *crinon*, lily, and εἶδος, *eidos*, a form.

because the receptacle and arms of some kinds resemble when in repose a closed lily or tulip,—are well exemplified in the recent *Pentacrinus*; the only known living form that is identical in structure with the numerous extinct tribes, that swarmed in the seas of the palæozoic and secondary ages.

The PENTACRINUS (*P. caput-medusæ*, *Wond.* p. 647), is an inhabitant of the Caribbean Sea, and but rarely obtained; there are specimens in the British Museum* and in the Hunterian Collection of the College of Surgeons.

This animal has a long stem or column, which is composed of pentagonal calcareous plates or ossicula, articulated to each other by radiated surfaces, and is fixed by the base to a rock, or other firm body. The column supports a vasiform receptacle or cup, formed of calcareous plates in close apposition; in which the digestive and other viscera are situated. The upper part of the receptacle is covered by an integument in which there is an aperture for the mouth. From the margin or brim proceed ten multiradiate arms, which subdivide into branches of extreme tenuity. On the upper and inner side of the arms are numerous articulated feelers or pinnæ. The ova are situated externally on and near the base of the arms, as in the Comatulidæ; a family of living Star-fishes, or more properly Crinoids, which have a receptacle, surrounded by articulated and multi-radiate arms, but are free animals, being destitute of a column.

In the living state of Pentacrinus, the skeleton—for such are the specimens in our museums—was of course covered and concealed by the soft integuments and tissues by which it was secreted. The ossicula composing the stem are pentangular, and very numerous; they have a central perforation, and their articulating surfaces are ornamented by

* Petrifactions, p. 77.

pentapetalous striations. There are numerous side-arms sent off from the column in groups of five, at uncertain distances.

The mouth is situated in the centre of a plated integument spread over the top of the receptacle. The arms, which arise from the margin of the latter, surround the mouth, and when spread out, with their numerous pinnæ or feelers expanded, form a net for the capture of prey; and are the organs by which the animal obtains food, and conveys it to the mouth.

Fossil Crinoidea.—The fossil crinoids, like the recent prototype above described, consist of an articulated column, and a receptacle formed of calcareous plates, and articulated arms or tentacula. They constitute two groups; the *Encrinites*, in which the ossicula of the column are subcylindrical and smooth; and the *Pentacrinites*, with a stem composed of pentangular ossicles, as in the living Pentacrinus.

The petrified remains consist of the ossicula of the column, arms, and tentacula; of the plates of the receptacle; and of the peduncle, or process of attachment by which the animal was fixed to the rock. The peduncle is in some species flat and expanded, like that of the *Gorgonia;* in others, it consists of long jointed processes. These several parts are commonly found detached, and intermingled with detritus in the strata; throughout extensive beds of encrinital marble, vestiges of the receptacle are but seldom discoverable. In some localities the skeletons are preserved entire, and lie expanded on the surface of the layers of shale, clay, or limestone, as if the animals had been enveloped by the soft deposit when alive in their native seas.

These remarks will serve to convey a general idea of the nature of the crinoidal remains which are scattered through certain rocks in such inconceivable quantities; for, much as the columns may differ in form, the ossicula in their markings, and the plates of the receptacle in their configuration

and ornament, the same general type of structure prevails throughout the family.

FOSSIL STEMS AND OSSICULA OF CRINOIDEA. — (*Bd.* pl. xlix.—lii. *Pict. Atlas*, pl. xlvii.)—The detached ossicula and stems are so common in many places, that they attracted the notice of the earlier collectors, by whom the single pieces were termed *trochites* (wheel-stones), and the united

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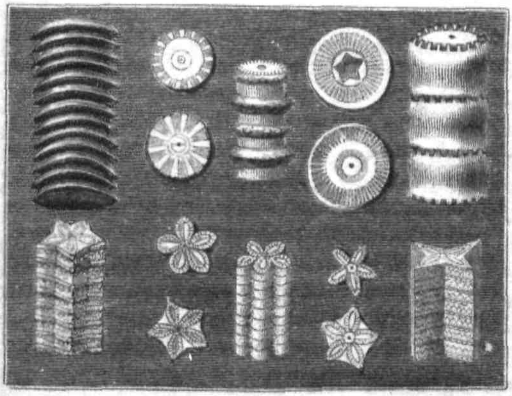


6 7 8 9 10

LIGN. 90. STEMS OF ENCRINITES AND PENTACRINITES.

Fig. 1.—Screw or Pulley-stone. *Derbyshire.*
2, 4.—Articulating surfaces of Encrinital ossicula.
3, 5.—*Entrochites*, or portions of stems of Encrinites.
6, 8, 10.—Portions of Pentacrinital stems.
7, 9.—Articulating surfaces of ossicula of Pentacrinites.

series *entrochites*. In the north of England these fossils are called *Fairy-stones*, and the circular perforated ossicula *Saint Cuthbert's beads*; the latter were worn as ornaments by the ancient Britons, and are occasionally found in tumuli.

These petrifactions present considerable variety in form, and in the markings on their articulating surfaces, which

are often radiated and sculptured in floriform and stellular figures (*Lign.* 90, *fig.* 7, 9, and *Lign.* 91, *fig.* 3, 4). The central perforation is small in some species, and large and pentagonal in others. The ossicula of the Encrinites often vary in size in the same column, being circular and elliptical, and thick or thin, alternately, as in the upper part of the column of the Lily Encrinite, *Lign.* 91, *fig.* 6; by which great flexibility and freedom of motion were obtained.

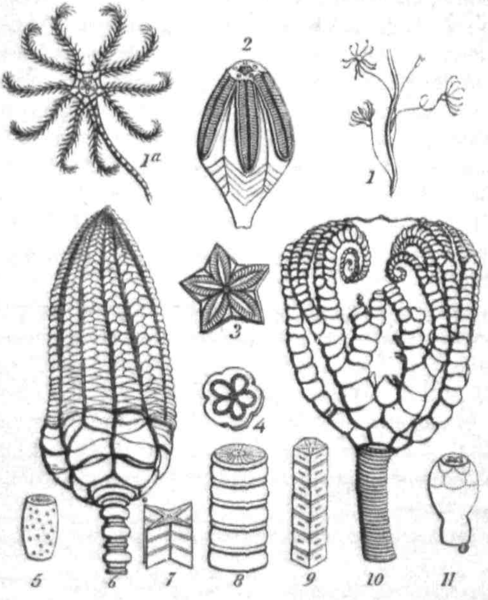
The pentagonal stems also display many modifications; some have five, others but four sides (*Lign.* 90, *fig.* 6, 8, 10, and 91, *fig.* 7, 9); in some the angles are acute, in others rounded.

PULLEY-STONES. *Lign.* 90, *fig.* 1.—The circular, or pentagonal channel formed by the united ossicula of the column, has given rise to the curious fossils called in Derbyshire the *Screw*, or *Pulley-stones*, which are flint casts of those cavities that occur in the beds of chert, interstratified with the mountain limestone. The siliceous matter, when fluid, must have filled up the channel and invested the stem: the original calcareous ossicles have since been dissolved, and the casts, now solid cylinders of flint, resembling a pulley, remain. The masses of chert are often impressed with the ornamented articulating surfaces of the trochites.

In the quarries on Middleton Moor, near Cromford, Derbyshire, where extensive beds of limestone composed of crinoideal remains are worked for chimney-pieces and other ornamental purposes, beautiful examples of these fossils may be obtained.* The cavities of the column and ossicles are often filled with white calcareous spar, while the ground of the marble is of a dark reddish brown colour; in other varieties of the Derbyshire encrinital limestones, the substance of the fossils is white, and the ground dark grey or brown.† A slab of this marble, with portions of columns

* See Excursions around Matlock, Part IV. of this work.

† Pict. Atlas, pl. xlix. figs. 1, 3, 6.



LIGN. 91. ILLUSTRATIONS OF CRINOIDEA.

Fig. 1.—Group of Living COMATULÆ; *nat.* (*Dr. Thompson.*)
1a.—A single COMATULA of the same group, magnified.
2.—PENTREMITES PYRIFORMIS. *Silurian, Ohio.*
3, 4.—Surfaces of two pentapetalous ossicula.
5.—A single Ossicle of an APIOCRINUS. *Chalk.*
6.—ENCRINUS LILIIFORMIS; the receptacle with part of the column attached; ½ *nat.* *From Brunswick.*
7.—PENTACRINITAL stem with four angles.
8.—ENTROCHITE, composed of five smooth ossicles.
9.—Quadrangular stem of seven ossicles.
10.—CYATHOCRINUS TUBERCULATUS. (*Sil. Syst.*)
11.—Receptacle of BOURQUETICRINUS; *from the Chalk. Lewes.*

lying in relief, and a polished section showing the inclosed entrochites, are figured *Wond.* p. 650.*

The *receptacle* which contained the viscera is extremely diversified in form, and in the number, shape, and arrangement of its plates: the annexed figure 2, *Lign.* 92, illustrates the several pieces that enter into its composition. The genera, or subgenera, are based on the modifications of shape and structure of the receptacle; and their names are composed of the termination *crinus*, or *crinites* (signifying stone-lily), with a term prefixed expressive of the generic character: thus we have *Apiocrinus*, or *Apiocrinites*, Pear Encrinite.†

The receptacle being round and inflated, and composed of pieces articulated with the stems, and supporting the arms by similar articulations, are the generic characters of *Apiocrinites* of Miller. When round but not inflated—*Encrinus*, when pentagonal, *Pentacrinus*. When the receptacle is composed of angular plates united at the edges and forming several series or stages, it constitutes the basis of the following genera: viz.—

Platycrinus; two series, the one of three, the other of five plates.

Pateriocrinus; three series each of five plates.

Cyathocrinus; three series of five plates, the last with five intercalated pieces.

Actinocrinus; several series of plates: the first composed of three, the second of five, and the others of many pieces.

Rhodocrinus; several series of plates that are covered externally with radiated ridges. The first course consists of

* Upwards of 80 figures of Encrinital remains are given in Pict. Atlas, pl. xlvii.

† The termination *crinus* is now generally employed, instead of *crinites*; the latter is preferable, as it indicates the fossil nature of the specimens. A more expressive name than *Encrinite* was suggested by Mr. Martin, of Derbyshire; that of *Stylastritæ* or Column-Stars.

three, the second of five, the third of ten, and the others of many plates.

Eugeniacrinus; of five pieces united into one receptacle.

This brief explanation will enable the student to comprehend the nature of the almost infinite variety of figure and ornament which the fossil crinoidea present, and the principles of nomenclature generally adopted by modern authors. To attempt an enumeration even of the genera would be inadmissible in these volumes. The late Mr. Miller's "Natural History of the Crinoidea or Lily-shaped Animals,"* will afford the student satisfactory information on this class of organic remains.†

APIOCRINUS (*A. Parkinsoni*). *Lign.* 92, *fig.* 4. (*Wond.* p. 652.)—The Apiocrinite or Pear-Encrinite of Bradford, from its size, and the abundance of its remains in one particular locality, is the most generally known of all the British fossil Crinoids. It abounds in the beds of oolite, in the quarries on the heights above the picturesquely situated town of Bradford, in Wiltshire. The receptacle, detached ossicula, and the pedicle, are very common; and in some instances the entire endo-skeleton, from the peduncle to the extremities of the arms, is preserved. The late Channing Pearce, Esq., of Bradford, by unremitting attention to the collection of these fossils, obtained the beautiful specimens deposited in the British Museum.‡

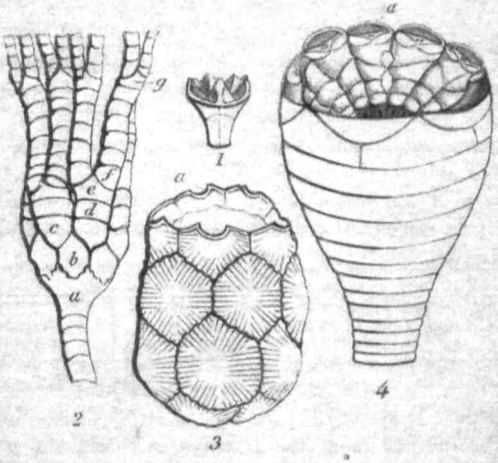
This Apiocrinite has a smooth receptacle of a pyriform shape, composed of large thin plates with radiated articulating surfaces; the stem is short and strong; the arms are simple, resembling those of the *Marsupite*; the peduncle spreads out

* Published in 1 vol. 4to. 1821, with coloured plates.

† A beautiful "Monograph on the Recent and Fossil Crinoidea," by Messrs. Austin, in 4to. is in course of publication, of which but eight numbers have appeared.

‡ Petrifactions, Room II. Wall-case G.

into an expanded base, which is firmly attached to the rock, like that of the Gorgonia, and is generally of a rich purple colour.*



LIGN. 92. FOSSIL CRINOIDEA.

Fig. 1.—EUGENIACRINUS. *Switzerland*
2.—CYATHOCRINUS PLANUS. *Mountain Limestone.*
a. Basal plate of the *receptacle.*
b. One of the plates composing the walls of the pelvis.
c. Costal plate.
d. Intercostal plate.
e. Scapula, or ossicle that receives the arm.
f. First ossicle of the arm.
3.—MARSUPITES MILLERI (G. A. M.). *Chalk, Brighton.*
a. The semilunar cavity for an attachment of the arm.
4.—APIOCRINUS ROTUNDUS, *Pear-Encrinite. Bradford.*
a. First ossicles of the arms.

Sir Charles Lyell mentions an interesting fact relating to the occurrence of these fossils in the Oolitic limestone at Bradford. In Burfield quarry, on the heights that overlook

* Pictorial Atlas, pl. xlix. Pulley-stones and Encrinital marbles; pl. l. Apiocrinites.

the town, a bed of limestone was exposed, the upper surface of which was incrusted with the stony peduncles or roots of *Apiocrinites*; upon this stratum was a layer of clay, in which were innumerable remains of receptacles and ossicula of stems and arms; some of the stems were erect, others prostrate, and throughout the clay were the dismembered remains. This submarine forest of Crinoideans must therefore have flourished in the clear sea-water, till invaded by a current loaded with mud that overwhelmed the living zoophytes, and entombed them in the argillaceous deposit in which their fossil remains are imbedded.*

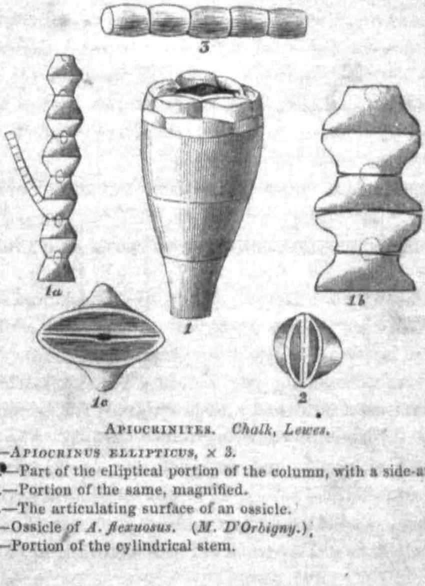
The constituent substance of the ossicula and plates of the Bradford Encrinite is calcareous, and has an oblique fracture; the colour is generally a light ochre, or a bluish grey.†

APIOCRINUS ELLIPTICUS. *Lign.* 93.—Detached ossicula of this small encrinite are abundant in the White Chalk; the receptacle is known to the quarrymen by the name of "*bottle.*" The pieces composing the column are cylindrical in the upper part, and elliptical and angular in the lower, and are articulated by a transversely-grooved surface. The two upper joints are enlarged, and support the receptacle, which is smooth and round (*fig.* 1). The column has articulated side-arms, and the base numerous jointed processes of attachment, which, when found apart from the column, have been mis-

* Burfield quarry, on the heights of Bradford, is the locality referred to; but I believe it is rarely that any specimens of the Apiocrinite are to be found in an erect position. I could not learn from any of the local collectors, that an example had been seen by them. When I visited the quarry in June, 1848, no good section of the beds was apparent: a few detached plates of Apiocrinites were the only relics we could meet with. Mr. Reginald Mantell, when engaged on the construction of the railway near Bradford, sought repeatedly, but in vain, to discover any Apiocrinites in an erect position, or as if lying on the spot where they grew.

† Pict. Atlas, pl. 1. contains figures of the Bradford Encrinites.

taken for a distinct type, and named "*Stag's-horn Encrinite.*"* The specimens figured *Lign.* 93, show the essential characters of this crinoid; when perfect, this species must have borne a general resemblance to the Pear Encrinite of Bradford.



LIGN. 93. APIOCRINITES. *Chalk, Lewes.*

Fig. 1.—APIOCRINUS ELLIPTICUS, × 3.
1a.—Part of the elliptical portion of the column, with a side-arm.
1b.—Portion of the same, magnified.
1c.—The articulating surface of an ossicle.
2.—Ossicle of *A. flexuosus.* (*M. D'Orbigny.*)
3.—Portion of the cylindrical stem.

BOURQUETICRINUS (D'Orbigny). *Lign.* 91, *fig.* 11.—Detached ossicles of other species belonging to the same genus, or to allied genera, are frequently met with in the Kentish and Sussex chalk. A common form is that figured in *Lign.* 91, which is part of the receptacle of a crinoid, named as above; it differs from the other Apiocrinites of the chalk in the articulating surfaces of the ossicles not being radiated,

* Pict. Atlas, pl. xlvii. fig. 31, p. 113. In the same plate there are figures of several specimens of detached portions of the stem of this species from the Kentish Chalk.

and in the receptacle, which is small and pyriform, not having a distinct cavity; there is only a median canal, which is seen in a vertical section: but the entire structure of the summit does not appear to be shown in any specimens hitherto observed.

ENCRINUS LILIIFORMIS (*Lily Encrinite*). *Lign.* 91, *fig.* 6. —This exquisite Crinoid is equally interesting and attractive to the amateur collector and the naturalist. Its remains do not occur in the British strata, and are only known in the muschelkalk of Lower Saxony. The specimens in this country are chiefly from Erkerode, in Brunswick; they are found in a layer, about eighteen inches thick, of a soft argillaceous cream-coloured limestone, chiefly made up of trochites, detached ossicula, and a few fragile shells and corals.

The receptacle of the Lily Encrinite is smooth, and in the form of a depressed vase; its base is composed of five plates, upon which are placed three successive series of other plates, with the uppermost of which the arms articulate. The stem is formed of numerous perforated round ossicles, articulated to each other by radiated grooved surfaces, and becoming somewhat pentangular, and alternately larger and smaller, towards the summit, to which the receptacle is fixed; a construction admitting great freedom of motion.*

This Encrinite when lying in relief on the rock, with its receptacle entirely or partially closed (see *Wond.* p. 548), so strikingly resembles the bud or expanding flower of a Lily or Tulip, as to justify the popular name of Stone-lily. An exquisite specimen is figured by Mr. Parkinson;† the British Museum possesses some fine examples.‡

Mr. Parkinson detected the animal membrane in ossicles of this crinoid, by immersing them in dilute hydrochloric acid.§ My friend Mr. Frederick Harford has repeated the experiment with success.

* Mr. Miller's work should be consulted for details of structure.

† Pict. Atlas, pl. xlviii.

‡ Petrifactions, p. 77.

§ See Pict. Atlas, pl. xlvii. fig. 47.

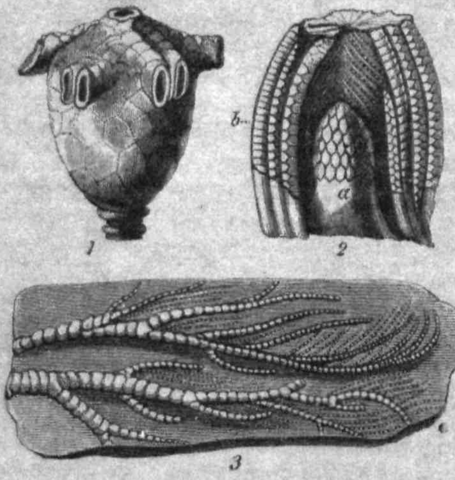
PENTACRINITES.—The description of the recent *Pentacrinus caput-medusæ* (*ante*, p. 282), illustrates the characters of the crinoideans whose fossil remains are so familiar to the palæontologist, under the name of Pentacrinites. In these animals the pieces composing the receptacle are firmly articulated together; the rays of the disk are fixed immediately to the summit of the column by special ossicula; and the stem is composed of angular pieces, which are generally pentagonal. The receptacle is small, and situated deep between the bases of the arms; it is closed above by an integument covered by minute plates or flat ossicles (*Lign.* 94, *fig.* 2). The fossil remains of several species are abundant in the Lias and Oolite of Dorsetshire, Somersetshire, &c. Slabs of limestone may be extracted with the surface covered with these crinoideans, spread out as if floating in their native element; very commonly they are transmuted into sulphuret of iron, or have a coating of brilliant pyrites.* The neighbourhoods of Lyme Regis, and Charmouth, are celebrated for these organic remains. A small specimen of the arms of a pentacrinite on Lias shale is figured in *Lign.* 94, *fig.* 3.

The arms in many of the plumose pentacrinites are very long and thickly beset with side-arms, and minute pinnæ, all of which are composed of separate articulated ossicles, so that the number of bones in a single endo-skeleton of those crinoids amounts to from fifty to one hundred and fifty thousand distinct pieces. The Briarean Pentacrinite,† so named from its numerous tentacula, is literally a tuft of articulated processes, appearing like a delicate fibrous plume attached to a stem. The *Pentacrinus Hiemeri* is a beautiful example of this type of crinoids, of which there is a noble group, comprising upwards of thirty individuals, on a slab

* Pictorial Atlas, pl. li. lii.

† Pictorial Atlas, pl. xlvii. The Briarean Pentacrinite is fully illustrated and described in detail in Dr. Buckland's Bridgewater Essay, p. 484.

in the British Museum,* exposed on the surface of the stone in as perfect a state as if just dredged up from the bottom of the sea. The pentacrinites are for the most part entire; the peduncle being fixed, and the column extending upwards in gentle undulations, and supporting the receptacle, from



LIGN. 94. ACTINOCRINITES, OR NAVE ENCRINITES.

Fig. 1.—ACTINOCRINUS PARKINSONI. (*Org. Rem.* ii. pl. xvii. *Pict. Atlas*, pl. ii.)
2.—Section of an ACTINOCRINUS. (*Miller's Crinoideæ*, pl. ii.)
a. Proboscideal protrusion of the plate and integument.
b. Sections of the folded or closed arms.
3.—Arms of a Pentacrinite, on Lias-shale; *Lyme Regis.*

which the arms are gracefully outspread in various attitudes. The structure of the receptacle, and of the arms, and the extreme delicacy of the finer tentacula made up of countless

* This species was named and figured by M. König in his "*Icones Fossilium sectiles*," pl. iii. fig. 29, in 1826. See Petrifactions, p. 88.

minute ossicula, are admirably shown in this unique and most instructive fossil.

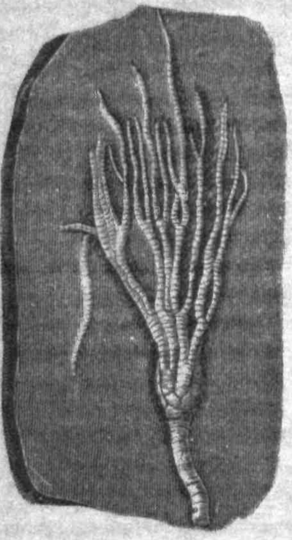
ACTINOCRINUS (*Nave Encrinite*). *Lign.* 94, *fig.* 1, 2. (*Wond.* p. 585. *Bd.* pl. xlvii.)—The column is formed of numerous round ossicula, possesses side-arms, and is fixed by root-like processes. The receptacle is of an irregular subspherical form, the arms passing off at right angles like the spokes from the nave of a wheel; hence the name. The base is composed of three plates which support five hexagonals and one pentagonal, and on these are three other series; from the upper margin of the last, five arms are given off. The receptacle is closed by a dome-shaped tesselated covering (*Lign.* 94, *fig.* 2), having on one side the opening for the mouth and vent. The specimen, *fig.* 1, is a receptacle without a stem, and with but a few joints of the arms; this is the usual state in which these fossils are obtained. *Fig.* 2 is an *Actinocrinite* in which part of the brim of the receptacle and of the arms has been removed in front, leaving a portion of the coalesced arms partially surrounding the proboscideal plated integument that covers the upper part of the receptacle; the figure is from Mr. Miller's work, and is introduced to illustrate the structure of these crinoideans.*

The external surface of the plates of the receptacle in the Actinocrinites, is generally covered with radiated markings and ridges, so that detached plates have been mistaken for those of Marsupites; see the restored figure of a Nave Encrinite, *Wond.* p. 654. In some species the receptacle is richly ornamented; but in the specimen figured, *Lign.* 94, *fig.* 1, the surface has been defaced in consequence of the fossil having been immersed in strong acid.

CYATHOCRINUS (*Cup-like Encrinite*). *Lign.* 95, and *Lign.* 92, *fig.* 2.—The column is formed of round, depressed, per-

* Miller's Crinoidea, fig. N. pp. 98—100.

forated joints, articulating by radiated surfaces ; pentagonal near the summit. The receptacle is composed of five pieces, succeeded by two successive series of five plates, with intervening plates, and supports five bifurcating, radiated arms.



LIGN. 95.
CYATHOCRINITES PLANUS; *nat.*
Mountain Limestone, Clevedon.

The Encrinites of this genus have a light and elegant appearance : the forms of the plates composing the pelvis, and of the ossicula of the arms, are shown in *Lign.* 92, *fig.* 2 ; which represents a specimen of *C. planus*, from the magnesian limestone of Somersetshire ; a beautiful example of the same species is figured in *Lign.* 95. The receptacle resembles in shape a depressed vase ; its upper part was probably covered by a plated integument, having an aperture in the centre as in the Actinocrinites. Cyathocrinites occur in the Silurian, Devonian, and Carboniferous formations.*

* A figure of Cyathocrinus rugosus is given in Pict. Atlas, pl. xlix. fig. 4. The same work contains coloured figures of Pentacrinus scalaris (Goldfuss), pl. xlvii. figs. 57, 64, 66 ; Pentacrinus basaltiformis, pl. xlvii. fig. 47.

A remarkable receptacle, with the tentacula partially introverted, is figured Pict. Atlas, pl. xlvi. fig. 2, from Gloucestershire ; and several beautiful examples of the arms, tentacula, &c. of Pentacrinites in Lias limestone and shale, in pl. li. figs. 9, 15, 16, and pl. lii. figs. 1, 2, 3, from Charmouth.

Rhodocrinus (*R. verus. Pict. Atlas*, pl. xlix. *fig.* 7, 8.).—A beautiful form, allied to the Antinocrinoids, occurs in the palæozoic rocks, and is named the Rose-encrinite by Miller. The column is cylindrical and traversed by a pentagonal canal. The rays or arms arise by a single ossicle and then bifurcate: the receptacle is formed of three, five, ten, and more numerous series of plates, which are ornamented externally. A fine example of a crinoid of this type (*Hypanthocrinus*) from the Wenlock limestone, is figured in the London Palæontological Journal, pl. xxi.

In Sir R. Murchison's Sil. Syst. all the crinoids of the Silurian deposits, then known, are figured. Several new genera are described by Professor McCoy, in the Synopsis of British Palæozoic Fossils.

Eugeniacrinus (*Clove-like Encrinite*). *Lign.* 92, *fig.* 1.—These little crinoids, which resemble a clove in form, are found at Mount Randen, in Switzerland, in Oolitic limestone. The receptacle is simple in structure, for it has but one series of plates; its cavity is very small. It had five arms: the articulating surface of the ossicles is radiated. When perfect this crinoidean must have somewhat resembled the Lily Encrinite, but the plates are all anchylosed, or blended together, which Mr. Miller attributed to an early stage of growth.

Pentremites pyriformis (*Pear-shaped angular Encrinite*). *Lign.* 91, *fig.* 2.—The column of this remarkable crinoid is short, and formed of cylindrical, perforated ossicula, with radiated surfaces, and has irregular side-arms. The receptacle is composed of polygonal plates, divided by five perforated grooves or furrows, which are of an elongated petalous form, and converge in a rosette on the summit. The marginal longitudinal rows of minute pores are not however for the passage of soft membranous feelers, as in the ambulacra of echinoderms, as was formerly conjectured, but are channels

for the transit of vessels that supply an infinite number of delicate simple tentacula, composed of extremely minute calcareous ossicula, as in the other Crinoidea, but not subdivided as in the Pentacrinites and Encrinites.

These articulated tentacula are arranged close together in longitudinal rows on the ambulacral spaces; there being two rows, each consisting of fifty tentacula, on every space. They are directed upwards towards the vertex of the receptacle, and appear to be the instruments for the capture and conveyance of food to the mouth.*

There are several species of *Pentremites*, some of which swarm in the cherty limestones of Kentucky. Mr. Say, to whom we are indebted for the first satisfactory investigation of these fossils, mentions that such is their abundance, that he has observed, on a piece of rock not larger than three inches by two-and-a-half, above twenty specimens lying in relief.

CYSTIDEA.—In the ancient fossiliferous strata there occurs a remarkable family of crinoideans, which is supposed to be restricted to the palæozoic ages; these fossils have been named by Von Buch, *Cystideæ*, from the body of the animal being wholly inclosed in a cyst, or box. The receptacle is of a spherical form, and composed of polygonal plates, articulated to each other; it has distinct apertures for the mouth, vent, and oviduct; the orifice of the latter is closed by valves. It has a short pedicle, but no arms have been discovered, and the Cystideæ are generally described as Crinoids without appendages of this kind. But in some members of this group, there are not only arms and tentacula, but likewise certain organs connected with the plates, which Prof. E. Forbes terms, "pectinated rhombs," the functions of which are not obvious. The arms more closely resemble those of

* See Dr. Fred. Roemer on jointed tentacles found on the ambulacral spaces of *Pentremites*, "Geol. Journal," vol. v. p. 8.

the Ophiuridæ than of the Crinoidea.* This order comprises several genera, and is the type under which the Crinoidea first appear in the natural records of our planet, according to the present state of our knowledge, and which becomes extinct before the advent of the Pentacrinites.

MARSUPITES MILLERI. *Lign.* 92, *fig.* 3, *Lign.* 96. (*Wond.* p. 652.)—The fossil remains of a genus related to the Encrinites, but separated from them by being unattached and free, having no column of support, were first described by the late Mr. Parkinson under the name of "*Tortoise Encrinite*" (*Org. Rem.* vol. ii. pl. xiii. fig. 24, *Pict. Atlas*, pl. xlvii.); but misled by the resemblance of some of the plates to those of certain species of Actinocrinites, Mr. Parkinson supposed the original to have possessed a jointed column. The examination of specimens obtained from the Chalk of Lewes and Brighton, enabled me to determine the true characters of the original; the purse-like form when the arms are closed suggested the name MARSUPITES (*purse-like*), by which it is now generally known; the specific name *Milleri*, is in commemoration of the late excellent and able author of the Natural History of the Crinoidea.

The receptacle of the Marsupite is of a sub-ovate shape, and rounded and entire at the dorsal extremity; a large central plate forms its base, on which is placed a successive series of pentagonal and hexagonal plates, the margins of which are in contact, but not anchylosed nor firmly united; to the periphery of this cup are articulated five arms, which subdivide into ten rays, or tentacula. The top of the receptacle was closed by an integument, covered by numerous small semilunar plates, in the centre of which was situated the oral aperture. The external surfaces of the plates of the receptacle are generally granulated and radiated, as in *Lign.* 92, *fig.* 3; but in some specimens the surface is quite smooth, a character which possibly may be specific. Some examples

* See a memoir on the British Cystidea, by Prof. Ed. Forbes; in the Mem. Geological Survey, vol. ii.

hav the surface granulated and rugous, and these Mr. Miller regarded as distinct, and named *M. ornatus*. I have not of late years been able to obtain specimens to determine this question.

The Marsupites vary in size, from an inch to three inches in length, exclusive of the arms. The receptacle is relatively very capacious compared with that of other crinoideans. The central plate is large, and of a pentagonal form, without the slightest indication of any column or process of attachment: five pentagonal plates are united to the sides of the basal plate, and above these a like number of hexagonals, which receive the five upper plates that constitute the margin; these have each a semilunar depression, to articulate with the first bones of the arms, or brachial appendages.

Detached plates and ossicula of marsupites are not uncommon in the Chalk of Kent and Sussex; nearly entire receptacles, filled with chalk or flint, are occasionally found in the pits near Lewes and Brighton; but examples with remains of the arms are extremely rare; and I have seen but one specimen (which I collected from the Sussex chalk), in which the plates of the integument that covered the opening of the receptacle are preserved.*

LIGN. 96.—MARSUPITES MILLERI, *nat.* *Chalk, Lewes.*

The Marsupite is an exceedingly interesting type, in a zoological point of view, since it forms a link that unites the Crinoidea with the Comatulæ, or feather-stars, which we shall presently notice. Its general form and habits are sufficiently indicated by the numerous specimens that have been collected in the Chalk of the south-east of England.

* It is figured in my *South D. Foss.* pl. xvi. fig. 6.

The body of the animal was inclosed in a crustaceous case formed of large plates, articulated to each other by suture; the mouth or oral aperture was situated in the centre of the plated integumental cover of the receptacle. The organs of locomotion and prehension consisted of five arms or brachial appendages, formed of ossicula as in the crinoidea, and the whole was invested with soft tissue or integuments. When floating in the water, the creature could spread out its tentacula, and form a net to capture its prey, and by closing them, secure it, and convey it to its mouth. The figure, *Lign.* 96, is restored from specimens which separately exhibit the parts here represented in connexion.

Fossil Asteriadæ.

The radiated animals, popularly called *Star-fishes*, from their stellular forms, are so abundant on our coasts, that the common five-rayed species must be familiar to all my readers who indulge in rambles on the sea-shore, and will serve as an illustration of the general appearance and structure of the beings whose petrified remains now claim our attention. This species belongs to the division of Asteriadæ, in which the rays are elongated, and far exceed in length the diameter of the disk; in another group (*Goniastea*, or Cushion-star), the body is angular, and the lobes or rays are short, and not longer than the diameter; while in a third subdivision (*Comatula* and *Ophiura*), the arms are distinct from the body, and articulated, elongated, and ramified, as in the *Crinoidea*.

The external surface of the common Star-fish is soft, and attached to a tough coriaceous integument, investing a skeleton composed of an infinite number of calcareous ossicula, arranged in regular series along the margins of the rays. Each ray has a longitudinal furrow, perforated at the sides by alternating rows of pores, through which tubular tenta-

cula are protruded. The mouth is situated in the centre of the under surface. Now if we imagine a Star-fish placed with its mouth upwards, and the five rays fringed with long articulated tentacula, as in the Comatula, and fixed by the centre of its dorsal surface upon a jointed stem, we shall have the essential characters of a crinoidean; and the animals of one recent tribe of *Asteriadæ* are actually in this condition in the earlier stage of their existence: these are the *Comatulæ*, or Feather-stars, in some of which (the *Euryale*), the arms are as numerously subdivided as in the Pentacrinites.*

From the importance of the Crinoidea in the economy of the ancient world, the history of the only type at present inhabiting Europe, the ancient seas of which swarmed with numerous forms of these beautiful creatures, presents many points of interest. The receptacle of the soft body of the *Comatula*, like that of the Crinoideans, consists of a cup-shaped calcareous base, which sends off from its margin five arms, that quickly subdivide, and are beset on each side with rows of articulated pinnæ; on the convexity there are also numerous slender, jointed, simple, tentacula. The mouth is situated in the centre of the area surrounded by the arms, and is capable of being elongated into a proboscis.* In the young state, the Comatulæ are attached by a jointed stem to other bodies, as shown in *Lign.* 91, *fig.* 1, which represents several of the natural size; *fig.* 1[a] is an enlarged view of an individual, and closely resembles an expanded Crinoidean. The stem is composed of about eighteen joints, which are pentangular; after a few weeks the Feather-star becomes detached from its peduncle, and ranges the sea in freedom.†

* The reader interested in this subject should peruse the charming volume on British Star-fishes and other Echinoderms, by Professor Edward Forbes. 1 vol. 8vo. John Van Voorst. 1841.

† The researches of J. V. Thompson, Esq. first brought to light these interesting facts in the Natural History of the Comatula; this

In the Comatulidæ, the arms are distinct from the body; these animals therefore closely approach the Crinoideans: in the true Star-fish, the angular processes, or arms, are an integral part of the body, containing a portion of the stomach, ova, &c., and are furnished with rows of pseudopodia.

Fossil Comatulæ have been discovered in the Solenhofen slate; and it is not improbable that some of the numerous Crinoideans may be Asteriadæ in the early stages of development.

In another group, Asteriadæ, (named *Ophiuræ* or Serpent-stars,) the rays are long and slender, and without grooves or tentacula, and are distinct from the body. These organs are extremely flexuous, and in some species beset with spines, and enable the animal to seize and entwine round its prey. The mouth is central, and there is an ovarian aperture at the base of each of the five arms.

Though the fossil Star-fishes comprise many extinct genera, they belong to the same families as the recent; and Comatulæ, Ophiuræ, and Asteriadæ, occur in the Lias, Oolite, and Chalk, in considerable numbers. Professor Edward Forbes has determined many of the British species, and it is to be hoped, will publish a monograph on the Fossil Asteriadæ, as a companion to his delightful work on the recent Star-fishes.

Fossil Ossicula of Star-fishes.—From the immense number of little bones which enter into the composition of the skeleton of a single Star-fish, and which are but slightly held together after the death of the animal and the decom-

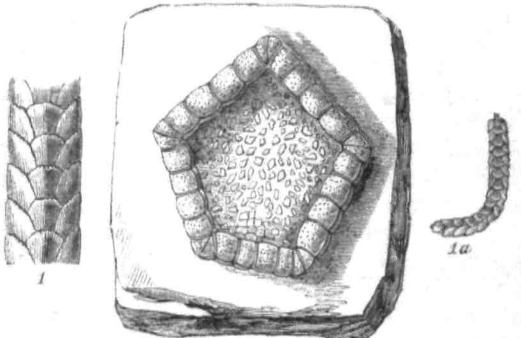
eminent naturalist first observed pedunculated Comatulæ in the Cove of Cork. When this discovery was first made known to me, I suspected that the *Marsupite* might have been pedunculated when young; but as very small specimens of this Crinoid are equally free from all traces of a stem as the adult, I was led to relinquish that opinion: still the collector, when searching for Crinoidean remains, should bear in mind the possibility of this having been the case.

position of the soft parts, we can understand how layer upon layer of ossicula of Asteriadæ may have been formed at the bottom of the cretaceous seas; as we find them in the quarries near Arundel, Worthing, &c. Whoever has witnessed the hauling up of the dredge off our coasts, and seen the mass of living Star-fishes which it brings up, as if the sea-bottom were a living bank of these Radiata, will not be surprised at the vast quantities of their fossil remains. This profusion of the living animals of this family, serves also to account for the enormous amount of those kindred but extinct forms, whose relics were the subject of investigation in the former part of the present chapter.

The ossicula vary in shape in different parts of the skeleton, and Prof. E. Forbes affirms, that the careful determination of their characters is of great importance, since they are the only parts of the animals likely to be preserved, and the shape of an ossicle is as truly indicative of a genus or species, as is that of a bone among the vertebrata. There is one ossicle situated on the side of the centre of the disk, which is worthy of remark, because it often occurs in the chalk mingled with the debris of the rest of the skeleton, and should be preserved by the collector. It differs from all the other bones in being marked with radiating grooves, and is called the madreporiform tubercle; it appears to be the analogue of the stem of the Crinoideæ, in other words, a rudimental condition of an organ, which is fully developed in that order of radiata.

OPHIURA. *Lign.* 97, *fig.* 1.—Several species of this genus, which is distinguished by the long, slender, serpent-like arms, and the circular disk covered with plates and spines, have been found in a fossil state: one species was discovered in the Lower Silurian deposits by Prof. Sedgwick, and other forms have been obtained from all the succeeding formations. The Lias near Lyme Regis and Charmouth has yielded many

beautiful examples of *Ophiura Egertoni*. Professor John Phillips has figured a species (*Oph. Milleri*, Geol. York, pl. xiii.) from the marlstone of Yorkshire, and a species from the Oxford Clay has been described as *Ophiura Prattii*. In the Cretaceous formation, remains of several species have been found. The first specimen from the Sussex Chalk that



LIGN. 97. FOSSIL REMAINS OF STAR-FISHES.

Fig. 1a.—Part of the ray of OPHIURA SERRATA; *nat. Chalk, Preston.* (*Mr. Walter Mantell.*)
1.—Portion of the same magnified.
2.—GONIASTER HUNTERI. *Chalk. Gravesend.*

came under my notice, was discovered many years since, by my son, in a quarry at Preston, near Brighton; the rays were admirably preserved, as shown in the portion figured in *Lign.* 97. An example of this species, with the disk entire, and portions of five arms, was found by Henry Catt, Esq. and is represented in pl. xxiii. fig. 2, of Mr. Dixon's work.*

* Three plates are devoted to the Cretaceous Star-fishes: the descriptions by Prof. E. Forbes comprise twenty-five species, belonging to the genera Oreaster, Goniaster, Stellaster, Arthraster, and Ophiura, all from the Chalk of Sussex and Kent.

GONIASTER. *Lign.* 97 and 98.—The star-fishes of this genus, popularly called *Cushion-stars*, are of a pentagonal form, and have a double series of large marginal plates, bearing granules or spines; the latter are seldom preserved in the fossils. The upper surface is nodulose.

LIGN. 98.
FOSSIL STAR-FISH. *Chalk, Kent.*
GONIASTER MANTELLI. (*sp. Forbes.**)

The detached ossicula of the skeletons of Cushion-stars are frequent in the White Chalk; and the large central bone, the *madreporiform tubercle*, which is present in the dorsal aspect of all star-fishes, is large, and therefore often observed, and may be easily mistaken for the base of a crinoidean receptacle. The layers in the Sussex Chalk composed of the exuviæ of star-fishes, as previously mentioned, are chiefly made up of ossicula of goniasters.

There are two species not uncommon in the Chalk, of which portions may generally be obtained from the pits near Gravesend; and occasionally very fine examples of the entire goniaster are met with. Mr. Dixon's work contains figures of several exquisite fossils of this kind. These organic remains were familiar to the early collectors: Mr. Parkinson figures several in Org. Rem. vol. iii. pl. i. and ii.*

Goniaster Hunteri (*Lign.* 97), has the body obtusely pentagonal, and the sides nearly straight; the superior intermediate marginal plates are four, equal, broadly oblong,

* Dixon's Cret. Foss. p. 332. † Pict. Atlas, pl. liii.

coarsely mamillato-punctate; the ossicula of the disk hexagonal.* This species is common in the upper chalk.

In *Goniaster Mantelli*, *Lign.* 98, the body is pentagonal, but the sides are curved, with projecting angles; the ossicula of the disk are punctated. The superior intermediate marginal plates are oblong, narrow, punctate, marginate, and six in number.†

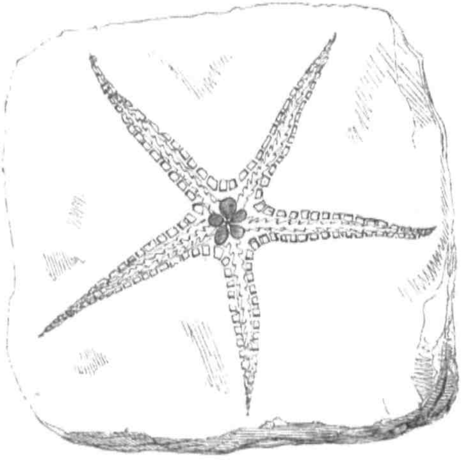
Specimens of these Goniasters are sometimes met with attached to a nodule of flint, in an extraordinary state of freshness; sharp imprints of the external surface, the skeleton having perished, are also found in flints, and, rarely, casts in pyrites. The whetstone of Dorsetshire often bears distinct moulds of Goniasters. I have found ossicula of this form of Star-fish in the London Clay of the Isle of Sheppey.

Asterias. *Lign.* 99.—The animals of this genus, of which the common Star-fish is the type, are stellate in form; the rays are flat, and extend from the body, of which they are a prolongation—not mere appendages. They have deep grooves or furrows bordered by marginal plates, which are continued to the extremities.

The Lias of Germany has yielded several species of Asterias; one of which is figured, *Lign.* 99. A very large species occurs in the Cornbrash of the Oolite of England. A magnificent specimen of *Asterias arenicola* (Goldfuss), from the calcareous grit, near Pickering, Yorkshire, measuring 10½ inches from the extremity of one ray to that of another, is figured in the London Palæontological Journal, pl. xvii. The same work contains admirable figures of *Ophiura Egertoni*, and *Oph. senatu* in flint, pl. xix.; *Oph. Milleri* in Staithes marlstone, and *Oph. Murravii*, pl. xx.; and two specimens of *Oph. Milleri* on the same slab of Lias from Staithes, near Whitby, pl. viii.

* Prof. Forbes, Dixon's Cret. Foss. p. 331. † Ibid. p. 332.

The Star-fishes of the British palæozoic strata are described by Prof. E. Forbes in the Memoirs of the Geol. Survey, *Decad.* 1.*



LIGN. 99. FOSSIL STAR-FISH. *Lias, Wirtemberg.*
ASTERIAS PRISCA. (*Goldfuss.*)

GEOLOGICAL DISTRIBUTION OF THE CRINOIDEA.—The great number of extinct forms of this order of Radiata in the most ancient fossiliferous deposits, is a remarkable fact, which has already been incidentally adverted to. In the palæozoic seas—including the Silurian, Devonian, Carboniferous, and Permian—the Crinoidea were represented by upwards of fifty genera, whose existence began and ended during that geological cycle.

* See also Prof. M'Coy's Lower Palæozoic Fossils, p. 58.

According to the present state of our knowledge all those peculiar types of radiated animals were created, and each lived through the destined period alloted to its race, and died out ere the deposition of the New Red Sandstone; not a single species, not a relic of the innumerable individuals that swarmed in the palæozoic oceans, has been observed in any strata above the Permian.

The Trias, which ranks as the earliest of the secondary formations, is characterized by the advent of two typical genera; the true Encrinus or Lily-encrinite, and the Pentacrinus; the former is unknown in any other deposits; the duration of its race was comprised within the Triassic epoch. The Pentacrinus, on the other hand, has been perpetuated through all the succeeding periods, and one species inhabits the present seas; *the sole existing representative of the most* ancient type of this order.

In the Oolite, another living form, the Comatula, first appears.

The ocean of the Cretaceous epoch was inhabited by five genera of Crinoids, unknown elsewhere; among them is that remarkable genus, the Marsupite.

The Crinoidea of the Tertiary seas are as few in number and variety as those of the present day; not a vestige of any of the ancient tribes has been discovered. M. D'Orbigny's *Tab.* 12 presents the phenomena thus briefly noticed, in a striking point of view.

From this review of the fossil Crinoidea and Asteriadæ, the student will be in some measure prepared for the collecting of instructive specimens from the immense accumulation of remains imbedded in certain strata of the Oolitic, Liassic, Carboniferous and Silurian rocks.

The British species of fossil Crinoidea amount to more than two hundred; and when the great number of bones

that enter into the composition of the skeleton of a single Pentacrinite or Encrinite is considered, the prodigious quantity of the fossil remains of these zoophytes in the ancient deposits may be readily conceived. Polished slices of the encrinital marbles of Derbyshire, and of the Lias limestones from Lyme Regis and Charmouth, should be obtained, as they show sections of the imbedded crinoidal stems and detached ossicula; and sometimes of the receptacles.

CHAPTER IX.

FOSSIL ECHINIDÆ, OR SEA-URCHINS.

LIGN. 100. TURBAN ECHINUS, WITH ITS SPINES; ½ *nat.*
(Hemicidaris crenularis, *Agassiz.*)
Jura limestone.

THE fossils we have now to examine are among the most familiar of the objects commonly known as petrifactions; for as the enveloping cases of the Echini possess considerable durability, they have served as moulds into which silex, calc-spar, limestone, pyrites, and other mineral substances, when in solution, or in a semi-fluid state, have percolated, and formed sharp and enduring casts, which exhibit the forms of the plates, and the disposition of the pores, striæ &c. of the original structures.

The common Echinus of our sea-coasts (*Echinus sphæra*), known by the name of Sea-egg, Sea-urchin, or Sea-hedgehog, presents the typical characters of this order of Radiata, which differs from the Crinoids and Star-fishes in the absence of arms.

The calcareous envelope of the Echinus, or shell, as it is popularly called, is composed of many calcareous, polygonal plates, closely fitted to each other, and arranged in regular and elegant patterns; appearing in the globular and spherical kinds like the lines of the meridian on a globe. The plates are disposed in ten vertical series, united by serrated sutures, and form sections, into which the envelope or case very commonly separates upon the decay of the investing integuments. Of the ten bands five are large and five small. The large bands (*areæ*) are each composed of a double row of plates, ornamented with tubercles supporting large spines (*Lign.* 100). The five narrower bands consist of much smaller plates, and the spines are minute, or altogether wanting; hence these bands appear like avenues through the spinous tracks, and have therefore been fancifully termed *ambulacra* or walks. They are the equivalents of the grooves or furrows of the Star-fishes (*Lign.* 108, *a.*); and are traversed by numerous pores, for the exsertion of tubular feet, or tentacula. Besides these rows of minute openings, there are two principal apertures, the *mouth* and the *outlet* or vent; and also a few large pores, commonly five, on the summit, for the exclusion of the ova, and the free admission of water.

The form and relative position of the parts above described, afford characters by which the order is divided into genera. The mouth, which is situated on the lower part, is in some species furnished with five sharp angular teeth, attached to a calcareous frame-work that admits of being protruded; this apparatus, when entire, commonly bears the name of "*Diogenes' lantern.*" The eminences on the surface

of the plates vary in size from mere granules, or papillæ, to large mamillated tubercles; they serve for the attachment of movable spines, which also present great variety of form and ornament. The spines have a cup-like cavity at the base which fits on the papillæ, and in many species are only supported by the capsular envelopment of the common integument; but in others, the large spines are attached by a ligament which passes from the centre of the socket, and is received in a perforation of the papilla of each tubercle, in the same manner as the *ligamentum teres* of the human thigh-bone. Transverse slices of the spines exhibit the internal structure, and are beautiful objects under the microscope.

There are also minute appendages to the integument, called *pedicellariæ*, or pinchers, of a very remarkable character, whose functions are not known. They are slender columnar bodies, each crowned with three calcareous teeth-like spines, beautifully sculptured, and which in some species are long and slender, in others short and obtuse. I have not observed any traces of these bodies, even in the best preserved echinites, but as they are as durable as the spines and case, they may exist in a fossil state.

This general view of the structure of the recent Echinites will enable the student to understand the nature of the fossil remains; for the parts above described are found more or less perfectly preserved, either in their natural arrangement, or separated and dispersed in the rock. The habits of these animals, of burrowing in the sand, were favourable to their preservation in a mineralized state; and in some of the oolitic limestones, hundreds of beautiful examples of Turban Echinites (*Cidares*), having their spines spread out on the face of the rock, are found lying in the positions they evidently occupied when living. The quarries near Calne and Chippenham, in Wilts, are celebrated for such fossils.

It was my intention to give figures of the genera into which the numerous fossil species have been divided by

modern authors; but I found the attempt hopeless, from the changes in nomenclature and arrangement which are constantly taking place. The monographs on the fossil Echinidæ, by Prof. E. Forbes, now in course of publication by the Government School of Mines, will, when completed, place this branch of Palæontology on a satisfactory basis.

For the convenience of study, the fossil Echini may be separated into three principal groups; viz. the CIDARITIDÆ, or Turban Echinites; the CLYPEASTRIDÆ, or Buckler-shaped Echinites; and the SPATANGIDÆ, or Heart-shaped Echinites.

CIDARITIDÆ. *Turban Echinites.*—In these sea-urchins the vent is situated on the summit of the shell, and is surrounded by five minute apertures for the exclusion of the ova. The mouth, or oral aperture, is placed directly opposite, in the middle of the base, or inferior surface. The mouth is large, and furnished with a powerful apparatus, armed with teeth; which is sometimes found fossil (see *fig.* 1, 3, *Lign.* 101). The structure of the animal, in consequence of the symmetrical position of the two chief outlets of the shells, is strictly radiated; that is, all the parts proceed from, or are arranged around one common centre. The tubercles are larger and fewer than in the other tribes of this family; they support long and powerful spines, which vary much in form and ornament in different species (see *Lign.* 102). The larger tubercles and spines are beset with smaller ones, disposed in regular series.

The Turban Echinites are the most ancient types of the order, some forms appearing in the Carboniferous deposit. The species are very numerous. The echinites of this group are subdivided into four tribes:

1. *Cidares,* properly so called.—In these the tubercles are perforated; the ambulacra narrow, and beset with granular tubercles, and the two lines of pores are close together. The pseudopodia can be protruded to a great length, even

beyond the spines, so as to reach objects the latter could not touch.

2. *Echini*, which differ from the above in the tubercles being *imperforate*, and the ambulacral area wide: the spines and tubes are of a moderate size.

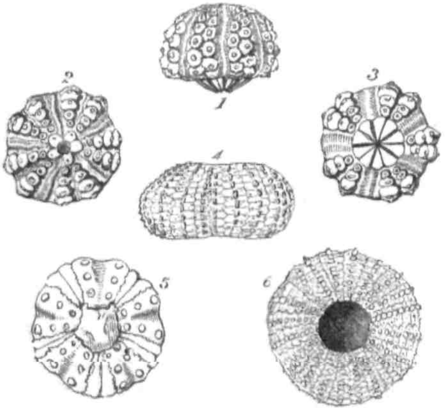
3. *Diademæ.*—The tubercles are perforated, and the ambulacra wide and studded with large tubercles.

4. *Saleniæ.*—The tubercles are imperforate, and relatively large; the chief distinction is a solid ovarian disk on the summit, composed of several large flat plates, anchylosed together.

The case of the Turban Echinites is composed of twenty vertical series of plates, the ambulacra, or porous grooves, forming continuous bands from the summit to the mouth, which is armed with five angular teeth. This tribe comprises many of the most elegant fossil species; those which, from their shape and highly ornamented surface, have received the popular name of Fairy's night-caps. The genus *Cidaris*, which is characterized by perforated spinous tubercles, affords the most beautiful examples, and these are occasionally found with the spines in contact; a circumstance less rare than might be supposed, when the nature of the attachment of these organs is considered; for, upon the decomposition of the integument, and the ligaments which connect the spines with the tubercles in a living state, these appendages quickly fall off, even in recent specimens.

The interesting fossil figured *Lign.* 100 (*ante*, p. 311), is a choice example of a Cidarite with the spines attached. This species (*Hemicidaris crenularis, Agassiz*) is said to be characteristic of the Upper Jura limestone of Switzerland, and was supposed to be identical with Mr. Parkinson's *Cidaris papillata var.* (*Pict. Atlas*, pl. lvi. fig. 6), from Calne, in Wiltshire; but spines like those of *Lign.* 100, do not occur in the English oolite. These spines are not homogeneous throughout; the central part appears to have been

of a less dense tissue than the outer coat, as is shown in the fractured spine in the figure. This structure does not exist in the spines of the depressed Turban Echinites, but is stated by M. Agassiz to prevail in all the species of the genus *Hemicidaris*, of which the fossil figured in *Lign.* 100 is the type.



LIGN. 101. CIDARITES FROM THE OOLITE AND CHALK.

Fig. 1.—HEMICIDARIS INTERMEDIA; view in profile, showing the teeth projecting: ⅓ *nat.* *Calne.*

2.—The same seen from above, displaying the outlet, and surrounding pores.

3.—The same, view of the base, displaying the mouth, surrounded by five angular bipartite teeth. The ambulacral tubercles at the base are omitted in the figure.

4.—DIADEMA ROTULARE (*Agass.*); viewed in profile: *nat.*

5.—A siliceous cast of another species of *Diadema*. *South Downs.*

6.—View of the base of DIADEMA ROTULARE. This species occurs in the so-called Neocomian Formation of France.

CIDARIS (*Hemicidaris?*) INTERMEDIA, *Lign.* 101, *fig.* 1, 2, 3.—The shell of this echinite, from the Oolite at Calne, so closely resembles that of *H. crenularis*, above described,

that without the spines it could not be distinguished.* It is of a depressed form, and has very long subcylindrical spines; a specimen is figured *Lign.* 102, *fig.* 9. It is this cidarite which occurs in such immense numbers in the Oolite at Calne, Chippenham, Faringdon, &c. Slabs of limestone are occasionally extracted from the quarries at Calne, with more than thirty of these echinites surrounded by their spines. I have one specimen, attached to a block of limestone, with fifty spines; but it is difficult to detach a perfect spine.

Cidaris Blumenbachii. *Lign.* 127, *fig.* 3.—This is another beautiful characteristic Turban Echinite of the Oolite. The tubercles are very large and prominent, and the spines remarkably neat, being covered with longitudinal granulated striæ; they are of an elongated cucumerine form, and homogeneous in structure (*Lign.* 127, *fig.* 5). They occur by hundreds in some of the layers of friable stone in the quarries around Calne.

Many species of Turban Echinites abound in the White Chalk, especially near Gravesend, Northfleet, Purfleet, Charlton, and other places in Kent; the softness of the cretaceous strata in those localities rendering the removal of the chalk an easy task. Splendid specimens, with the spines and tubercles almost as fresh as if recent, have rewarded the patience and skill of collectors. The British Museum contains many fine examples, especially a specimen of *Cidaris clavigera* from Charlton, with sixteen spines, and the dental apparatus *in situ*.†

* Mr. Woodward. I am indebted to this gentleman for many valuable remarks on fossil Echinoderms.

† Several coloured figures of Cidarites and spines are given in Pict. Atlas, pl. liii. and lvi. A fine series of Chalk specimens are figured in Dixon's Fossils, tab. xxv.; many from the choice cabinet of Henry Catt, Esq. of Brighton.

The collection of Chalk Cidarites with their spines, formed by W. H. Taylor, Esq. F.G.S., of Winterslow-place, Brixton, is the most splendid assemblage of these fossils I have seen.

DIADEMA. *Lign.* 101, *fig.* 4, 6.—The shell in this genus is of a more depressed form than in Cidaris; there are two rows of large tubercles, which are crenulated and perforated, on the ambulacra as well as on the interambulacral spaces. The spines are slender and annulated. Mr. Woodward remarks that the common Chalk species referred by authors to this genus, belong to the sub-genus *Cyphosoma* of M. Agassiz, in which the tubercles are imperforate. There are nearly fifty fossil species known, and they range from the Lias to the Chalk. The recent analogues inhabit the seas of warm regions.

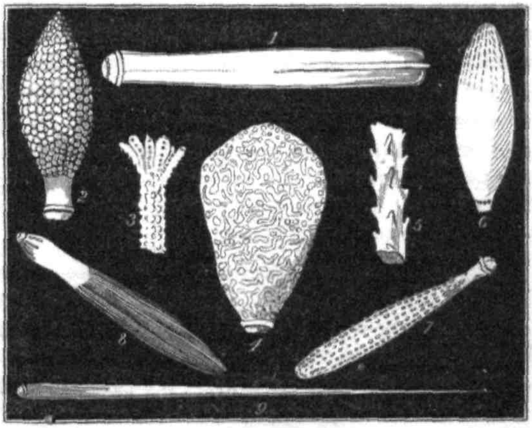
ECHINUS.—The shells of the genus Echinus resemble those of Cidaris in their general structure, but the tubercles are imperforate. More than twenty fossil species are described, from the Oolite and Chalk.

SALENIA.—In the greensand pits near Faringdon, in Berkshire, which abound in fossil sponges and other poriferæ (*ante*, p. 228), there are immense numbers of a small elegant Turban Echinite, which belongs to the genus thus named by the eminent zoologist, Dr. J. E. Gray, of the British Museum. The collector will easily recognize these sea-urchins by the plated summit. The shell has five ovarian and five interovarian plates, and an eleventh or odd one. The tubercles are crenulated. The common species at Faringdon is *S. petalifera*, of Desmarest. Two species of this genus, viz. *S. scutigera* and *S. stellulata*, from near Warminster, are figured in *Pict. Atlas*, pl. liii. fig. 12, 13.

Cidarites of New Zealand.—Detached plates and spines of sea-urchins, belonging to the family Cidaritidæ, have been discovered by Mr. Walter Mantell, in the Ototara limestone of New Zealand; which is a fawn-coloured stone, composed of foraminiferæ, like the Chalk, and containing terebratulæ, corals, and teeth of sharks.*

* Geol. Journal, vol. vi. p. 319.

SPINES OF CIDARITES. *Lign.* 102.—Allusion has been made to the immense numbers of the spines of two or three kinds of Cidarites that occur in the oolitic limestones of certain localities. The spines of other species and genera abound in the Chalk, Greensand, &c.; occurring detached,

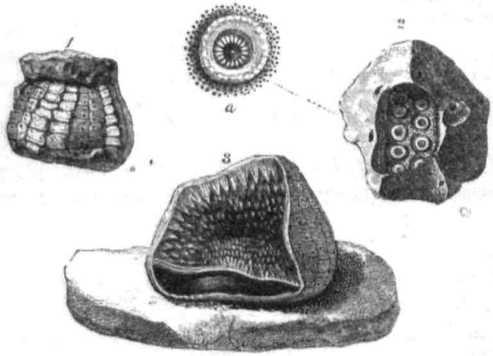


LIGN. 102. FOSSIL SPINES OF CIDARITES.

Fig. 1.—Spine of ACROCIDARIS nobilis (*Agassiz*).
2.— —— CIDARIS cucumifera.
3.— —— —— stemmacantha.
4.— —— —— meandrina.
5.— —— —— spinosa.
6.— —— —— clunifera.
7.— —— —— sceptrifera.
8.— —— —— Parkinsoni.
9.— —— HEMICIDARIS intermedia.

and intermingled with corals, shells, and the usual fossils of those deposits. There is great variety in the form, size, and sculpture of these organs. In the subjoined *Lign.* 102, a few distinct kinds are represented.

FLINT CASTS OF TURBAN ECHINITES. *Lign.* 103.—The siliceous casts of the shells of the Turban Echinites are interesting objects, for they are often beautiful models of the interior. A specimen of this kind is represented in *Lign.* 101, *fig.* 5. Casts of the larger Cidarites are often seen on the ploughed lands of the South Downs, in beds of gravel, and among the shingle on the sea-shore of chalk districts; appearing as flattened spherical bodies, with a circular protuberance at each pole, and vertical rows of nodular projections. Impressions of the external surface of the cases are also frequent on chalk flints, and exhibit exquisite casts, in intaglio, of the mamillated tubercles, and ambulacral grooves and pores.



LIGN. 103. ECHINITAL REMAINS IN FLINT. *Chalk. Lewes.*

(*One-third the natural size.*)

Fig. 1.—Cast of an ANANCHYTE, showing the form of the plates.
2.—Imprint of a segment of a CIDARITE on a pebble.
a.—One of the impressions of a spinous tubercle: *nat.*
3.—Portion of an ANANCHYTE, having the cavity of the shell covered at the bottom with flint, and lined above with crystals of carbonate of lime.

A fragment of a flint, impressed by a portion of a Cidarite, is represented *Lign.* 103, *fig.* 2. The perforations around

the imprint indicate tubular cavities in the flint, formed by the spines, and show that these processes were attached to the shell when the latter was enveloped by the fluid silex; the case and the spines having since perished. But in the Chalk, exquisite specimens of Cidarites occur with the case perfect, and filled with flint: examples of this kind are often attached to a nodule by the slender column of silex that fills up the aperture of the shell. The mineralized condition of the originally friable calcareous cases of Cidarites and other Echini, is worthy of attention: for whether the shell or spines be imbedded in chalk, flint, or pyrites, if the structure and form remain, the constituent substance is invariably opaque crystallized carbonate of lime, having an oblique fracture.

As this conversion of a crustaceous envelope into calc-spar is constant, it has probably resulted from the peculiar nature of the original animal structures; but the cause of such transmutation is unknown.

CIDARITIDÆ OF THE PALÆOZOIC ROCKS.—Three genera of this family, comprising several species, have been discovered in the carboniferous limestone of Northumberland and Ireland. One genus is undistinguishable from Cidaris; and the species are placed under that name in Mr. Morris's *Cat. Brit. Foss.*

These fossils have been figured and described by Prof. John Phillips, and Col. Portlock. Prof. M'Coy, with his accustomed penetration and sagacity, has ascertained, that notwithstanding the general resemblance between the Cidarites of the secondary and those of the palæozoic formations, the latter are constructed on an entirely different plan. In the turban echini of the secondary, tertiary, and modern seas, the interambulacral plates always consist of *two* rows; but in the palæozoic Cidarites there are *three* or some greater odd number of these plates. This eminent naturalist, there-

fore, places the earliest type of Echinidæ at present known in the order *Perischoechinidæ.* The case is spheroidal, formed of more than twenty rows of plates; five ambulacra composed of two rows of pentagonal plates each; rows of interambulacral plates, three, five, or more, terminating dorsally in five large pentagonal ovarian plates.

As in the more recent forms, these Cidarites are separable into two groups or families; one in which the spiniferous tubercles are imperforate as in the Echinus (*Palæchinidæ* of M'Coy); the other with numerous small secondary tubercles and a few large primary ones, perforated for the ligament of the spine as in Cidaris (the *Archæocidaridæ* of M'Coy).*

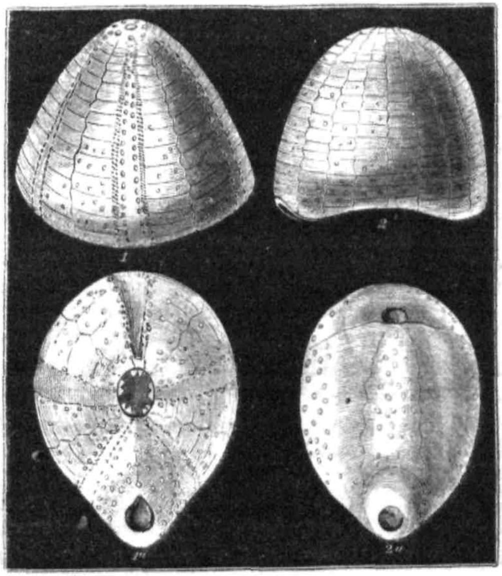
CLYPEASTRIDÆ.—The shell in this family of sea-urchins, is oblong or rounded; the mouth is of an angular form, and situated in the middle of the base or inferior face; it is furnished with well-developed dental organs. The outlet is distant from the summit. The tubercles are mere granulations, and the spines proportionally small. This group is subdivided into two tribes; the GALERITIDÆ (*helmet-like*), and the CLYPEIDÆ (*buckler-like*).

GALERITES ALBO-GALERUS. *Lign.* 104.—The tribe of which this genus is the type has the shell inflated, orbicular, oblong, or pentangular. The ambulacra are simple, never petalloid; the poriferous zones extend uninterruptedly from the summit to the mouth.

In the species figured *Lign.* 104, *fig.* 1, the shell is of a conical form, in some varieties subpentagonal; narrowest at the hinder part. The mouth is of a decagonal shape, and armed with teeth: it is situated in the centre of the base (*Lign.* 104, *fig.* 1ᵃ); the outlet is near the posterior margin of the base. The surface of the shell is covered with gra-

* Prof. Sedgwick's "British Palæozoic Fossils," p. 124.

nulations irregularly distributed. This species, which received the name of *albo-galerus*, from its fancied resemblance to the white conical caps of the priests of Jupiter, occurs in great numbers and perfection in the Kentish chalk; it is less



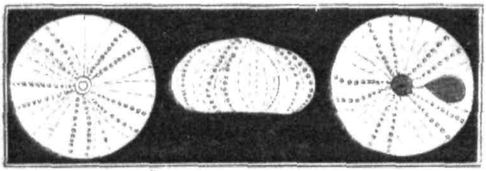
LIGN. 104. ECHINITES FROM THE CHALK. *Lewes.*

Fig. 1.—GALERITES ALBO-GALERUS: *nat.*
1*a*.—Base of the same, with the five teeth.
2.—ANACHYTES OVATUS: ½ *nat.*
2*a*.—Base of the same.

common in that of Sussex. Siliceous casts of the shell are constantly found among the drift and gravel, and on the ploughed lands of chalk districts; they are popularly termed "*sugar-loaves.*". The specimens obtained from the chalk,

when filled with flint, yield exquisite casts, if the shell be dissolved in dilute hydrochloric acid; by this means the form of the plates, and casts of the minutest ambulacral pores are obtained.

HOLECTYPUS (*Galerites*) INFLATUS. *Lign.* 105.—In certain kinds of Galerites, the shell is strengthened internally by five strong ribs or projections, which of course leave corresponding deep furrows or channels on the flint casts moulded in them; such fossils are not numerous on the ploughed lands of the South Downs. These echinites are placed by M. Desor in the genus of which an example is figured in *Lign.* 105.



LIGN. 105. HOLECTYPUS (*Galerites*) INFLATUS.

Kimmeridge Clay, Switzerland.

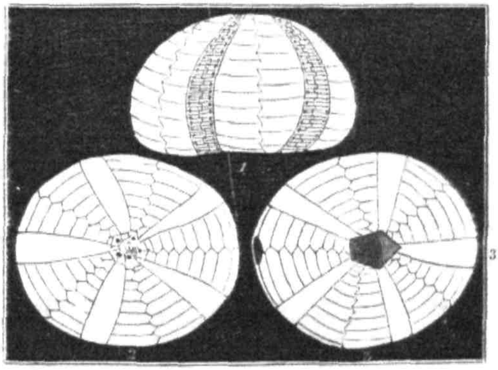
The left-hand figure shows the summit; the middle figure a profile; and the right hand, a view of the base, with the mouth in the centre, and the outlet towards the margin. (*M. Agassiz*).

The shell is hemispherical, and circular; the base flat; the tubercles are disposed in series; the inside of the case is supported by ribs.

DISCOIDEA (*Galerites*) CASTANEA. *Lign.* 106.—The Galeritidæ, which have a polygonal mouth, with the tubercles disposed in vertical rows from the summit to the centre of the base, as in the Cidarites, instead of being uniformly spread over the surface, as in *G. albo-galerus*, are placed in the genus *Discoidea*, by M. Agassiz.

A species, in which the mouth is pentagonal, and the

outlet on the margin, occurs in the Chalk-marl of Sussex, Dorset, and the Alps; a specimen is figured in *Lign.* 106.



LIGN. 106. DISCOIDEA (*Galerites*) CASTANEA. *Chalk-marl, Dorset.*

Fig. 1.—Profile. The pores and plates of the ambulacra only are inserted in this figure.
2.—View from above.
3.—The base, showing the central pentangular mouth, and the vent in the margin.

The CLYPEIDEÆ differ from the tribe of echinites last described, in the ambulacra being petaloid, that is, of a leaf-like shape, and disposed in a stellated figure on the upper part of the shell. The ambulacra do not extend to the mouth. The shell is generally of a depressed form; and the petaloid ambulacra in many species appear like an elegant star, richly fretted, spread over the shell. There are numerous species of this type, both recent and fossil; many of the latter, being of a large size, are beautiful objects in a cabinet of petrifactions.

CLYPEUS SINUATUS (*Pict. Atlas*, pl. liv. fig. 1).—Of this genus, which is the type of the tribe, a large species, *C. sinuatus*, is very common in the Oolite of Wilts, Gloucester-

shire, and Oxfordshire, and must be familiar to collectors. The shell is circular, and much depressed; and has five petaloid ambulacra: the odd interambulacral area forms a deep furrow in which the outlet is situated: the mouth is median, pentagonal, and surrounded by a strong margin. The coloured figures in *Pict. Atlas*, pl. liv. will enable the student to recognize these fossils without difficulty. Splendid specimens of an allied form (*Clypeaster*) occur in the tertiary limestone of Malta, (*Pict. Atlas*, pl. lvi. fig. 7,) and are not uncommon in collections.

NUCLEOLITES (*Wond.* p. 328). — There is a small type belonging to this family, of which several species are so abundant in the Oolite, Greensand, and Chalk-marl, that a brief notice of their characters may be useful. The shell is oblong and inflated, rounded in front and flat behind. The pores are united by grooves; the outlet is in a deep furrow on the superior face; the mouth is sub-central. One species occurs in the Tertiary strata, and there is a recent species inhabits the seas of Australia. There are coloured figures of Nucleolites in *Pict. Atlas*, pl. liv. fig. 5, pl. lv. figs. 6, 8.

SPATANGIDÆ.—In this tribe of echinites, the case is oblong or cordiform. The mouth, elongated transversely and destitute of proper jaws, is situated in front of the centre of the base, near the anterior border of the periphery. The outlet is towards the posterior margin. The tubercles and spines are very small. Four subdivisions are established, namely,—

1. *Ananchytes.*—A thick and oval shell; the ambulacra simple and converging towards the summit; the mouth transverse; the outlet is situated on the inferior face. (*Lign.* 104, *fig.* 2.)

2. *Spatangus.* — This name is now restricted to those Spatangidæ in which the ambulacra are petaloid, the external row of pores slightly elongated, and the inner rows round.

3. *Micraster.*—By this term are now distinguished the

Spatangidæ which have the ambulacra depressed, and the shell cordiform. The pores of the even ambulacra are united by a furrow. The vent is on the posterior face. The common chalk Spatangus belongs to this genus. (*Lign.* 107.)

4. *Holaster.*—The shells are heart-shaped; the ambulacra simple, and converging towards the summit; the mouth is transverse; the outlet is within the posterior face.

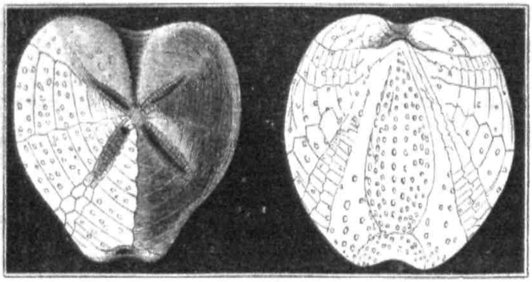
Ananchytes ovatus. *Lign.* 104. *fig.* 2.—These sea urchins are among the most characteristic of the fossils of the Upper Chalk, and are peculiar to the Cretaceous formation. They are readily distinguished by their elevated helmet-like form, and by the transverse mouth and oblong outlet situated on the inferior face of the flat base, and towards the margin. (*Lign.* 104, *fig.* 2[a].)

The vernacular names of "*Shepherd's Crown*," and "*Fairy Loaf*," indicate the form of these abundant fossils. The shell is oval in its longest diameter; flat, or nearly so, below; and rounded, conical, and somewhat laterally compressed towards the summit. The ambulacra are five, between double lines of pores; the tubercles are minute and scattered; the substance of the shell is of great thickness. More than twenty species of the genus are known.

The helmet Echinites, like the preceding, have given rise to innumerable siliceous casts, which are found associated with those of other forms in the Drift, on the ploughed lands, and among the shingle on the sea-shore; they are often placed as ornaments on the mantel-shelves of the cottagers. A flint cast of an Ananchyte, in which the plates were partially separated, is represented *Lign.* 103, *fig.* 1. The shells are sometimes filled with pyrites; and occasionally are found partially empty, with crystals of calc-spar symmetrically arranged on the inside of the shell, parallel with the rows of ambulacral pores. *Lign.* 103, *fig.* 3, is a remarkable

example, in which flint occupies the base of the shell, while the upper surface is lined with crystals of calcareous spar.

MICRASTER COR-ANGUINUM (*Snake-heart*). *Lign.* 107.—Of this genus there are many species in the Chalk. This type



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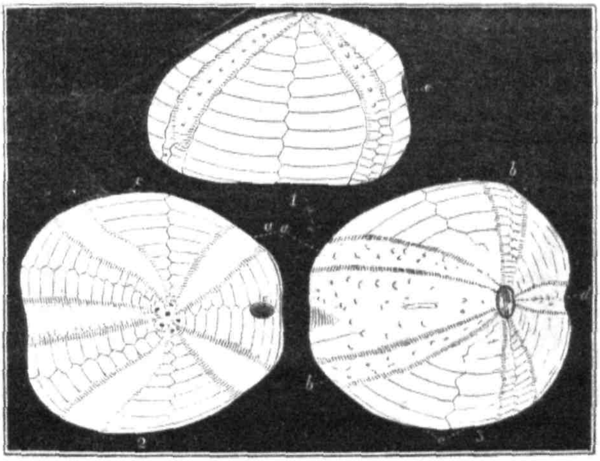
LIGN. 107. MICRASTER (*Spatangus*) COR-ANGUINUM.

Chalk. Lewes.

Fig. 1.—View from above, showing the petaloid ambulacra.
2.—View of the base, with the mouth.

of Spatangidæ are more or less oval, elongated, and heart-shaped, wider before than behind, with a sulcus, or furrow, in front. The shell is fragile, and composed of large polygonal plates; the tubercles small and irregularly distributed; the spines are short. The mouth is transverse, situated anteriorly, and protected by a strong projection of the odd inter-ambulacrum, which is named the lip. The vent is terminal, and placed above the margin. There are but four ambulacra, and these are incomplete, comparatively of small extent, and situated in deep furrows. A large and new species of Micraster (*M. cor-bovis*, of Prof. E. Forbes), from the Sussex Chalk, is figured in Dixon's *Fossils*, pl. xxiv. figs. 3, 4, p. 342.

TOXASTER (*Spatangus*) COMPLANATUS. *Lign.* 108.—In this form of Spatangus (constituting the genus *Toxaster*



LIGN. 108. TOXASTER COMPLANATUS.

Greensand. Switzerland.

Fig. 1.—Profile.
2.—View of the summit, showing the *Vent* at the side; *e.*
3.—View of the base, displaying the situation of the mouth, and the union of the five *ambulacra*; their pores are not introduced in figs. 2 and 3.
a. The narrow porous divisions of the shell, termed *Ambulacra.*
b. *Interambulacral spaces.*
c. *Areæ*, or spaces covered by the wide plates.
d. The *Mouth.*
e. The *Vent*, or *Outlet.*

Agass.), the ambulacra are not depressed or furrowed, as in the preceding echinites, nor petaloid (*leaf-shaped*), as in those which M. Agassiz denominates true Spatangi, but converge to a point on the summit, as is shown in *fig.* 2; the external rows of pores are elongated horizontally, and form

a kind of furrow. The odd ambulacrum is in a deep groove. The mouth is transverse, *fig.* 3, *d*; and at the anterior part of the inferior face there is a depression, which results from the convergence of the ambulacral areæ towards that point. The vent is in the posterior face. This species is from the *Neocomian* strata of France; I introduce it to illustrate the characters of several other echinites, which the French geologists suppose to be confined to the so-called Neocomian formation; but which also occur in the Upper Greensand of Blackdown.

HOLASTER is another genus of Spatangidæ established by M. Agassiz, for those echinites that are heart-shaped, with simple ambulacra converging towards the summit. The mouth is elongated transversely; the outlet is on the posterior face. A specimen first described in my *Foss. S. D.* (*pl.* xvii. *fig.* 9, 21), as *Spatangus planus*, is common in the Lower Chalk, and Chalk-marl, and abundant in the Firestone Malm-rock.

Our limits will not allow of a more extended notice of the fossil *Echinidæ*. The student should consult the Memoirs on the genera, now in course of publication at the Government School of Mines, by Professor Edward Forbes; the plates are exquisite, as works of art, and the descriptions all that can be desired.

Mr. Dixon's work contains three excellent plates of cretaceous Echinites. Several chalk species are figured in my Foss. South Down. The numerous coloured figures of fossil sea-urchins in the Pictorial Atlas of Organic Remains, have already been mentioned.

GEOLOGICAL DISTRIBUTION OF ECHINITES.—No vestiges of this order of radiata have been discovered in the Silurian deposits: the earliest known occurrence of any type is in the

Carboniferous formation. The most ancient Echinidæ, according to the present state of our knowledge, are the Cidares, in the modified form previously noticed,—*Archæocidaridæ* (*ante*, p. 322).

In the Trias another type appears, *Hemicidaris*, which holds an intermediate place between the Cidarites properly so called and the Diadema.

In the Oolite, and Jurassic formations, numerous forms are for the first time met with, constituting the genera Echinus, *Clypeus*, *Disaster*, *Holectypus*, Diadema, Nucleolites, &c.

The Cretaceous seas swarmed with echini belonging to genera of which no traces have been found in earlier rocks; viz. Holaster, *Salenia*, *Micraster*, Salerites, Discoidea, *Ananchytes*, Cassidulus, &c.

In the Tertiary formations, Spatangus, Scutella, Clypeaster, and other new genera appear, and many of the ancient ones are absent; or at least have not been observed. Of the genera printed above in italics, no living species are known.

ON COLLECTING AND DEVELOPING FOSSIL ECHINODERMATA.—In the previous remarks on the fossil remains of radiated animals, we have pointed out those remains that are the most important and instructive, and should be sought for by the student. Thus, in collecting Crinoids, the receptacle or body should be the principal object of research, and if only detached plates can be extracted from the rock, their relative position should be carefully noted, and the specimens glued to a card or board, in their natural order; and some of the ossicula of the column, and of the arms, or tentacula, be placed with them.

Mr. Miller dissected specimens of every genus, and has figured the separate plates or bones that enter into the composition of the receptacle,* and arms. Traces of the ten-

* Natural History of the Crinoidea.

tacula, and their subdivisions, must be sought for, and if discovered, should be removed with the stone to which they are attached, and the block be afterwards reduced in size by a mason's saw, and not by the blows of a hammer, which might displace the ossicula.

If imbedded in Lias shale, or other fragile material, a thick slab should be removed, for greater safety in conveyance; this, when reduced to a convenient size and thinness, may be imbedded in a tray with plaster of Paris, or glued to a piece of thin, well-seasoned mahogany, or deal. The specimens of the *Pear Encrinite* of Bradford, and of the Pentacrinites from Lyme Regis, in the British Museum,* were prepared in this manner.

The crinoideal remains in Chalk belong but to few genera; they merely require the usual manipulation of cretaceous fossils. The collector, however, should remember that the ossicula and plates of the receptacle (as for instance of the *Marsupites*), are but slightly adherent to each other, and the chalk must not be wholly removed, or these parts will become detached.

The receptacles of the Apiocrinites of the chalk are rarely found with more than a few joints of the column attached; and I believe no vestiges of the arms have been observed: these parts are therefore desiderata, and should be diligently sought for: the radicles of these crinoideans are long, articulated, and branching, and without due caution may be mistaken for the arms, or for another species. The first remark will also apply to the Marsupite; any specimens with but a few ossicula of the arms are very precious. I may observe that there is yet much to learn as to the number of species and genera, and the peculiar characters of the Crinoidea of the chalk, and that any addition to our knowledge on this subject will be valuable.

The *Asteridæ* are so simple in form and structure, that it

* Petrifactions, p. 78.

is unnecessary to offer any suggestions for their development; of course they must not be removed from the stone.

Among the detached ossicula dispersed through the chalk, the student will remember that the large *madrepore-like* tubercle of the Star-fishes, (*ante*, p. 304,) may often occur. It may easily be mistaken for an encrinital body, or for a coral, but an accurate inspection will show that it is not composed of anchylosed plates, like the receptacle of an Apiocrinite, but has surfaces for attachment to other ossicula; while the ends, which in a crinoideal column would have radiated surfaces, are rounded and entire.

In collecting Echinites, much caution is required in dissecting specimens surrounded by spines. If imbedded in hard limestone, or in laminated clay, it is scarcely possible to preserve the spines in connexion with the shell; but it often happens that the Cidarites of the Oolite are attached by the base to the solid limestone, and the case with the spines is imbedded in sandy, friable aggregate, not difficult of removal. A specimen in my cabinet, with upwards of fifty spines attached to the shell, was obtained under such circumstances.*

The Chalk Echinites will be found to possess spines more frequently than is commonly supposed, if care be taken to explore the surrounding chalk before it be removed. I have often procured Cidarites with spines, when there were no apparent vestiges of these appendages, by carefully scraping away the surrounding mass until the extremity of a spine appeared, and then tracing it up to its connexion with the shell; another point was discovered by further removal, and that was developed in the same manner; and at length a Cidaris with several spines was obtained. The chalk around the mouth should always be cautiously removed in the dentated species, in the hope of preserving the teeth, as in the specimens, *Lign.* 101, *fig.* 1, and *Lign.* 104, *fig.* 1.

* Now in the British Museum.

As the shells of Chalk Echinites, when hollow, are often lined with crystals (see *Lign.* 103, *fig.* 3), it is worth while to break all indifferent specimens of the common species, with the chance of obtaining an example of this kind.

The chalk must not be *scraped* off from the crust or shell of the Echinites, or the minute granulations and papillæ will be injured or removed; it should be flaked off with a blunt point.

In friable arenaceous strata, as in some of the Maestricht and Tertiary deposits, the Echinites may be extricated in as perfect a condition as if fresh from the sea; it is, indeed, probable, from the habit of these animals of burrowing in mud and sand, that in many instances they were entombed alive by the sediment in which their fossil remains are imbedded.

Beautiful Cidarites and their spines may be collected in the Oolitic strata at Calne, Chippenham, Bath, &c.; and in the coralline Oolite near Faringdon; and of Saleniæ, in the Greensand gravel-pits near that town.

The Upper Greensand near Warminster, and at Chute Farm, near Heytesbury, abounds in small Cidaridæ and other echinites. The large sinuated Clypeus is found in great perfection in the Oolite at Malton, Cheltenham, Gloucester, &c.

The cretaceous echinites are to be met with in most localities of the white chalk. The chalk pits in Kent, especially at Gravesend, Northfleet, Chatham, &c. are rich in Cidarites, and their spines. The Galerites, and Ananchytes, are also very fine and numerous; and the softness of the chalk renders their extrication from the stone a delightful task for the young geologist.

Specimens of the common kinds of fossil Echinoderms may be obtained at moderate prices of the dealers named in the Appendix.

There is a matchless suite of fossil Echinidæ in the British Museum, which has been arranged and named by Mr. S. P. Woodward, and is now the most instructive and interesting collection extant. It contains examples of the following genera, viz., Ananchytes, Echinocorys, Echinolampas, Holaster, Galerites, Cidaris, Diadema, Acrosalenia, Glypticus, Disaster, Pygurus, Clypeaster, Scutella, Salmasis, Echinocyanus, &c. There is also a good series of echinital spines.

CHAPTER X.

FOSSIL FORAMINIFERA — MICROSCOPICAL EXAMINATION OF CHALK AND FLINT.

"Where is the dust that has not been alive?"
YOUNG.

THAT those infinitesimal forms of animal existence which swarm throughout the waters of the ocean, but whose presence can only be made manifest by the aid of the microscope, are preserved in a fossil state,—that their durable remains constitute mountain ranges, and form the subsoil of extensive regions,—and that the most stupendous monuments erected by man are constructed of the petrified relics of beings invisible to the unassisted eye,—are facts not the least astounding of those which modern Geology has revealed.

This interesting field of research, which the labours of that eminent observer M. Ehrenberg first made known, has since been explored by other naturalists, and in every part of the world many of the Tertiary and Secondary deposits have been found to contain microscopic organisms in profusion. At present this branch of palæontology is in its infancy, and it offers to the young student an inexhaustible and most attractive path of scientific investigation; it possesses, too, this great advantage over many others, that it can be pursued at home, and the materials for its prosecution are everywhere at hand. Unlike my explorations in the Wealden, in which a few fragments of bones, or teeth, scattered at wide intervals through the rocks, and in localities many miles apart, were

often the only reward of a day's labour, here, in the quiet of my study, I may discover in a few atoms of flint, or grains of chalk, picked up by the road-side, the fossil remains of beings as interesting and extraordinary as the extinct colossal reptiles of Tilgate Forest.

The microphytes, or fossil Diatomaceæ, described in a previous chapter, (*ante*, p. 93,) were formerly classed with the organisms that now claim our attention, under the name *Infusoria;* from the belief that generally prevailed among naturalists, of their animal origin. In fact, some eminent microscopic observers, while admitting the vegetable character of Xanthidium, Micrasterias, &c. consider the Naviculæ, Ennotiæ, &c. as belonging to the animal kingdom.

Thus Dr. J. W. Bailey, in a late "Memoir on the Microscopic Organisms in Various Localities of the United States," divides these bodies into three groups; viz. *Infusoria*, *Desmidieæ*, and *Diatomaceæ;* with the remark, that he has separated the two latter tribes from the Infusoria, because so many distinguished naturalists consider them decidedly to belong to the vegetable kingdom: "but," he adds, "while I believe that no positive line of separation can be drawn between certain animals and vegetables, I am yet disposed to regard the *Desmidieæ*, from the sum of all their characters, as most nearly allied to admitted vegetables; while the *Diatomaceæ*, notwithstanding Mr. Thwaites's interesting observations on their conjunction,* still seem to me, as they have always done, to be true animals. There is such apparent volition in their movements, such an abundance of nitrogen in the composition of their soft parts, and such

* The mode of fructification, or *conjunction*, as it is termed, in the Algæ, consists in the adhesion of two cells or frustules together, and their fusion into one; from their united contents a mass of granular substance is produced, that becomes consolidated and forms the spore or fruit, which, when arrived at maturity, is set free by the bursting of the cell. Mr. Thwaites has ascertained that the fructification is similar in the Diatomaceæ.

resemblance between the stipitate Gomphonematæ and some of the Vorticellæ, that I should be still disposed to class them as animals, even if Ehrenberg's observations of the retractile threads and snail-like feet of some of the Naviculæ should not be confirmed." *

Thus, whilst referring Closterium, Arthrodesma, Euastrum, Xanthidium, Micrasterium, &c. as vegetables, to the Desmidieæ, Dr. Bailey places *Actinocyclus, Campilodiscus, Coscinodiscus, Eunotia, Navicula, Gomphonema, Pinnularia, Triceratium, &c.* among the Diatomaceæ, as animals.

Of the animal nature of the microscopic objects which now require our attention, there is however no question, although the zoological position and affinities of many of the organisms included in this survey are still but imperfectly determined.

The animals designated *Foraminifera*,† or Rhizopoda,‡ are of a more simple structure than the Polypifera and Echinodermata described in the previous chapters; yet as their relics are for the most part presented to the notice of the geologist as aggregations of shells, forming extensive beds of limestone, it will be convenient to treat of them in this place.

The fact that the fossil remains of *Foraminifera*, and of *Mollusca*, alike consist of shells, and constitute strata identical in mineral characters, and deposited under like physical conditions, renders the examination of these *Microzoa* § a fit introduction to the study of the durable remains of the higher order—the Mollusca.

* Smithsonian Contributions, vol. ii. p. 34.

† FORAMINIFERA, *i.e.* bearing foramina—a name derived from the minute openings in the shells and their septa.

‡ RHIZOPODA; root-like feet; from the long fibrous processes, or pseudopodia.

§ MICROZOA; from μικρὸς, *mikros*, small, and ζῶον, *zoon*, animal; a convenient term to denote minute animal organisms whose forms can only be defined by the aid of the microscope.

It is scarcely more than a hundred and twenty years ago, that the existence of this numerous order of microzoa was first made known to naturalists by *Beccarius*, who detected a considerable number of species in the sand on the shores of the Adriatic. But the structure of the animals that secreted these shells is a discovery of comparatively modern date. The early collectors classed these microscopic bodies with the shells of true mollusca; and even M. D'Orbigny, whose elaborate researches justly constitute him a high authority in this branch of natural history, in his first memoir, in 1825, described the involuted discoidal forms as Cephalopoda. This error was corrected by the investigations of M. Dujardin, who in 1835 satisfactorily demonstrated that the Foraminifera are animals of the most simple structure, and entirely separated by their organization from the Mollusca.

But the true nature of this class is so little understood by British collectors of fossil shells,—of course I mean the uninitiated, and the amateur naturalist, for whose use these unpretending pages are designed,—that in order to invest the study of the fossil species with the interest which a knowledge of the structure and economy of the living originals can alone impart, I must give a history of the recent forms somewhat in detail, taking M. D'Orbigny as my chief authority.*

The FORAMINIFERA are marine animals of low organization, and, with but few exceptions, extremely minute: in an ounce of sea-sand between three and four millions have been distinctly enumerated. When living, they are not aggregated, but always individually distinct; they are composed of

* The best work for the student to consult is M. D'Orbigny's "Foraminifères Fossiles du Basse Tertiaire de Vienne, Autriche." Paris, 1846. 1 vol. 4to. with plates. I rejoice to learn that a Monograph on the British Foraminifera is in preparation by Dr. Carpenter and Professor Williamson: than whom there are none more competent.

a body, or vital mass, of a gelatinous consistence, which is either entire and round, or divided into segments, placed either on a simple or alternate line, or coiled in a spiral, or involuted round an axis. This body is covered with an envelope or shell, which is generally testaceous, rarely cartilaginous, is modelled on the segments, and follows all the modifications of form and contour of the body. From the extremity of the last segment there issue sometimes from one, sometimes from several openings of the shell, or through the numerous pores or foramina, very elongated, slender, contractile, colourless, filaments, more or less divided and ramified, serving for prehension, and capable of entirely investing the shell.

The body varies in colour, but is always identical in individuals of the same species; it is yellow, ochreous, red, violet, blue, &c.

Its consistence is variable; it is composed of minute globules, the aggregation of which determines the general tint. It is sometimes entire, round, and without segments, as in *Gromia, Orbulina*, &c., which represent at all ages the embryonic state of all the other genera. The animal increases by gemmation, each segment being essentially distinct, but connected with the preceding one by a tube or neck. When the body is divided by lobes or segments, the primary lobe, as in the permanent condition of the Gromia, is at first round or oval, according to the genus; once formed it never enlarges, but is enveloped externally by testaceous matter.

The segments, which successively appear, are agglomerated together in seven different ways, and these modifications are the basis of M. D'Orbigny's classification. The discoidal forms, as the *Rotalia, Rosalina, Cristellaria*, &c. are involute, like the Nautilus, and divided by septa or partitions, which, like the enveloping shell, are perforated. The lobes of the body *occupy contemporaneously every chamber*, and are connected by a tube that extends through the entire series. In

the spiral form, as the Textularia, &c., the same structure is apparent.

Whatever the form of the body, the filaments always consist of a colourless transparent matter; they are capable of being elongated to six times the diameter of the shell. They often divide and subdivide, so as to appear branched; and though alike in form in the different genera, vary much in their position. In some species they form a bundle which issues from a single aperture, and is withdrawn into the same by contraction; in others, the filaments project only through each of the pores in that portion of the shell which covers the last segment: in many they issue from both the large aperture and the foramina. These filaments or pseudopodia fulfil in these animals the functions of the numerous tentacula in the Star-fishes; serving as instruments of locomotion and attachment.

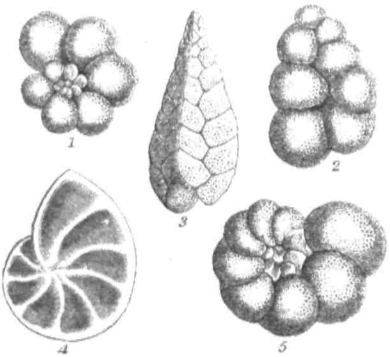
Neither organs of nutriment nor of reproduction have been discovered. In the genera having one large aperture from which the filaments issue and retract, we can conceive nutriment to be absorbed by that opening; but this cannot be the case in the species which have the last cell closed up; in these the filaments issuing through the foramina are probably also organs of nutrition. M. D'Orbigny considers the Foraminifera as constituting a distinct class in zoology; though less complicated than the Echinoderms and the Polypifera in their internal organization, they have the mode of locomotion of the first; while by their free, individual existence, they are more advanced in the scale of being than the aggregated and immovably fixed animals of the latter class.

But though I consider the animal of the Foraminifera as single, and the additional lobes, or segments, as the continuous growth of the same individual, I must state that some eminent naturalists regard the entire structure as a series of distinct individuals, developed by gemmation from the first formed segment, like the clusters of the compound

Tunicata; and not as a single aggregated organism, made up of an assemblage of similar parts indefinitely repeated. In a palæontological point of view, it matters not which opinion is adopted.*

CLASSIFICATION OF THE FORAMINIFERA.—The number of genera is so great, that I can only attempt to convey a very general idea of the principles of classification adopted by M. D'Orbigny, and give a few illustrations of some of the most abundant fossil species.

That the reader may be cognizant of the usual aspect of these shells, five specimens from the Chalk, belonging to as



LIGN. 109. FORAMINIFERA.
Chalk. Charing.

Fig. 1.—GLOBIGERINA CRETACEA; *the original is $\frac{1}{60}$ of an inch in diameter.*
2.—TEXTULARIA GLOBULOSA; $\frac{1}{40}$.
3.—VERNEUILINA TRICARINATA; $\frac{1}{30}$.
4.—CRISTELLARIA ROTULATA; $\frac{1}{40}$.
5.—ROSALINA LORNEIANA; $\frac{1}{40}$.

many genera, are here represented (*Lign.* 109); the deposit whence they were obtained will be described hereafter.

* See a masterly paper on the strutture of Nummulina and Orbitoides, by Dr. Carpenter; Geol. Journal, vol. vi. pp. 21—39, with admirable representations of the structural details.

As the mode in which the growth of the body, and consequently of the shell, takes place, differs greatly in certain groups, an obvious and natural arrangement is suggested, by which the class is divided into seven orders:—

1. The primary, or simplest type; one segment or cell; as in *Orbulina.*

2. The segments arranged in circular lines; as in *Orbitolina.*

3. *Segments disposed in a straight or arched single line;* successively increasing from the first to the last cell; as in *Nodosaria, Lign.* 111.

4. Segments, spirally and discoidally disposed, on the same plane, like cells of the Nautilus; as in *Cristellaria, Lign.* 109.

The same type, but coiled obliquely, and inequilaterally, like the shells of Gasteropoda; as in *Globigerina, Lign.* 109, *Rosalina, Lign.* 109.

5. Segments developed alternately on the right and left of the first, and successively on each side the longitudinal axis; as in *Textularia, Lign.* 109.

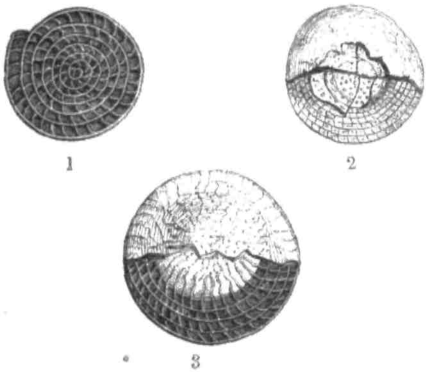
6. Arrangement of the segments combining the modes of 4 and 5; that is, the segments are formed alternately, but the whole are coiled spirally, either obliquely, or on the same plane: as in *Amphistigena.*

7. Segments round a common axis, on two, three, four, or five, opposite faces, returning after each entire revolution; the new cells being placed exactly on the preceding series; as in *Quinqueloculina, Pict. Atlas,* pl. lxii. fig. 12.

The Foraminifera vary considerably in magnitude; by far the greater number of species are invisible to the unassisted eye, and the aid of a lens or microscope is required to define the structure even of the largest; yet many are of sufficient size to be recognized, as for example the *Spirolinæ, Lign.* 112. A few genera are from a quarter of an inch to nearly an inch in diameter, as the *Orbitoides Mantelli* of the

tertiary formations of North America,* and the *Nummulina*, commonly termed *Nummulites*, of Europe, *Lign.* 110.

We will now describe the genera selected for illustration, commencing with the large and well-known type, whose aggregated remains form extensive beds of crystalline limestone in the Alps, and in Asia, and Africa.†



LIGN. 110. NUMMULITES, OR NUMMULINA; *nat.*

From the Great Pyramid of Egypt.

Fig. 1.—Transverse section of a NUMMULITE, showing the form and arrangement of the cells.
2, 3.—Specimens with part of the external plate removed.

NUMMULINA LÆVIGATA. *Lign.* 110.—The shell is of a discoidal or lenticular form, composed of numerous cells, concentrically arranged round an axis on the same plane; both sides of the disk covered by a smooth thick plate.

Under the name of *Nummulites*, from their resemblance to a piece of money, the fossil shells of this genus of Foraminifera have long been known to naturalists, and are figured

* Dr. Morton's Synopsis of the Organic Remains of the Cretaceous group of the United States. Philadelphia, 1824, p. 45, pl. v. fig. 9.

† Geol. Journal, vol. v.

in many of the early works on petrifactions. They occur in immense quantities in certain rocks, and are of all sizes, from a mere point, to disks an inch and a half in diameter; thus exceeding in magnitude all other animals of this class.

Perfect specimens appear as a calcareous solid circular body, of a lenticular shape; smooth, and slightly convex on both sides, and without any visible structure. On splitting the fossil transversely, or rubbing down one of the convex planes, a series of minute cells, arranged in a discoidal spire, is brought to view, as shown in *Lign.* 110, *fig.* 1. But this description gives a very inadequate idea of the complicated and exquisite structure of the original, which has been admirably worked out by Dr. Carpenter. This eminent physiologist has shown that each chamber was occupied by a living segment, connected with other segments by one or more tubular prolongations, which absorbed nutrition from without, by means of filamentous pseudopodia, that projected through a system of passages leading from the medial plane to the external surface.* A figure of the supposed form of a living Nummulina is given in *Pict. Atlas*, p. 187.

The specimens figured in *Lign.* 110 are from the limestone that forms the foundation rock of the Great Pyramid of Egypt, and of which that structure is in great part composed. Strabo alludes to the Nummulites of the Pyramids, as lentils which had been scattered about by the artificers employed on those stupendous monuments, and become stone.† Silicified masses of Nummulites are occasionally

* Geol. Journal, vol. vi. p. 21. See also a paper by Prof. Williamson, "On the minute Structure of the Calcareous Shells of some recent species of Foraminifera." Trans. Microscop. Soc. vol. iii. p. 105.

† An interesting fact was communicated to me by a friend who lately descended the Nile; the Nummulitic limestone rocks are in some parts of the course of the river washed into the stream, and becoming disintegrated, the Nummulites are set free, and re-deposited in the recent mud of the Nile.

met with; polished slices of such specimens are richly figured by the sections of the inclosed Foraminifera.

The Nummulitic limestones are of the Eocene or ancient Tertiary epoch, as the labours of Sir Roderick Murchison in the Alps, Apennines, and Carpathians first established: Nummulites are unknown in the Secondary formations.*

Orbitoides.—The fossil bodies thus named are disciform, like the Nummulites; and one species, which forms the constituent substance of ranges of limestone mountains, 300 feet high, near Suggsville, in North America, was first described by my lamented friend, the late Dr. Morton, of Philadelphia, as *N. Mantelli,* in his work on the Cretaceous Fossils of the United States.

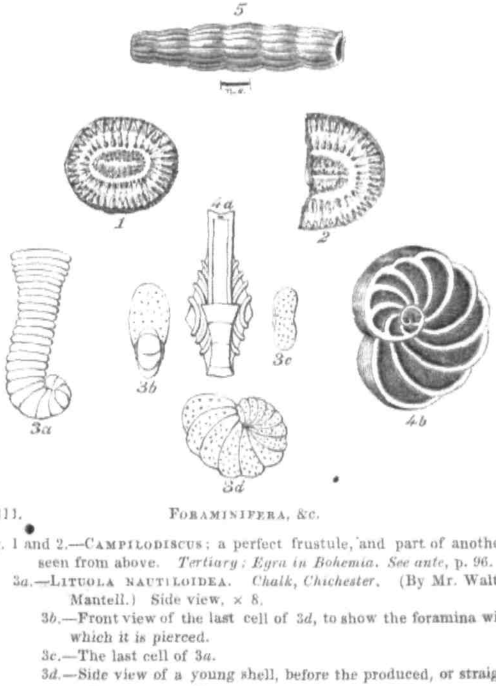
The discovery that the Nummulitic deposits of the Old World were of the tertiary period, directed attention to their supposed geological equivalents in America; and on a careful examination of their fossils, the rocks proved to be tertiary, and the shells true Foraminifera allied to the Nummulites, but generically distinct.† A reference to Dr. Carpenter's memoir, previously cited, is necessary to comprehend the complicated structure of these fossils.‡

Siderolina, or *Siderolites,* is a genus of Foraminifera, which may be described as Nummulites, in which the turns of the spire are intercepted by elongated appendages, that project beyond the periphery of the disk, and produce a stellated figure. These fossils abound in the cretaceous strata of Maestricht.

Fusulina.—The shell is fusiform, being elongated transversely to the axis; the cells are divided internally by constrictions. Only one species is known, (*F. cylindrica,*) and this is confined to the Carboniferous formation; it is the most ancient or earliest type of the class, according to the present state of our knowledge.

* Geol. Journal, vol. v. † Manual of Geology, p. 208.
‡ Geol. Journal, vol. vi.

Nodosaria. *Lign.* 111, *fig.* 5.—Straight, elongated cells placed end to end, separated by constrictions; the last



Lign. 111. Foraminifera, &c.

Fig. 1 and 2.—Campilodiscus; a perfect frustule, and part of another, seen from above. *Tertiary; Egra in Bohemia. See ante, p. 96.*

3a.—Lituola nautiloidea. *Chalk, Chichester.* (By Mr. Walter Mantell.) Side view, × 8.

3b.—Front view of the last cell of 3d, to show the foramina with which it is pierced.

3c.—The last cell of 3a.

3d.—Side view of a young shell, before the produced, or straight part appears. × 20.

4a.—Flabellina Baudonina. *Chalk.* (M. D'Orbigny.) A young individual seen in profile. × 12.

4b.—The same, viewed laterally, shows the oblique arrangement of the cells.

5.—Nodosaria. *Chalk, Chichester.* (By Mr. Walter Mantell.) The line below indicates the natural size.

formed cell has a round central aperture. Several beautiful species abound in the Chalk; specimens often occur adhering to the surface of the flint nodules.

Nodosariæ are abundant in tertiary deposits. Mr. Walter Mantell discovered Foraminifera of this genus in the blue clay of Kakaunui, in New Zealand.

CRISTELLARIA. *Lign.* 109, *fig.* 4.—The shell is in the form of a compressed Nautilus; it has a single aperture, which is situated at the angle of the keel; the cells are oblique.

This genus comprises seventy fossil species, which occur in the Lias, Oolite, and Chalk. Living species are abundant in almost every sea.

FLABELLINA. *Lign.* 111, *fig.* 4*a*.—In a young state, this shell, like the preceding, resembles that of a Nautilus, and the cells are oblique; but in the adult, are of a zigzag (chevron) form. It has a single round aperture. *Fig.* 4*a* shows a young individual, seen in profile; *fig.* 4*b* a lateral view, exhibiting the obliquity of the cells.

Species of Flabellina are often found in cretaceous strata. The genus is not known in a recent state.

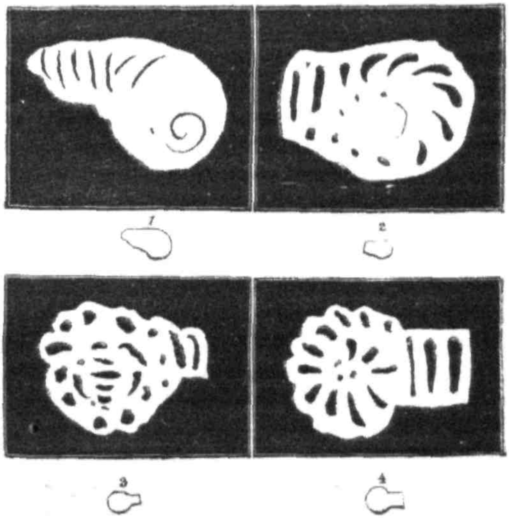
POLYSTOMELLA.—In its general form this genus resembles the other nautiloid shells above described, but its structure differs essentially; for there are several apertures along the side of the shell, as well as the opening in the last segment. The cells are simple, and each is a single cavity. The figures and details of structure, given by Professor Williamson, must be referred to, for an insight into the organization of this beautiful and complicated type of Foraminifera.* One species of Polystomella is said to occur in the Chalk; I have not detected this genus in our cretaceous deposits. Recent species swarm in our seas; and may be easily obtained from the mud and sand on the shores at Brighton.†

LITUOLA. *Lign.* 111, *fig.* 3*a*.—In a young state the shell is nautiloid, as in *fig.* 3*b*, 3*d*; but becomes produced by age, and assumes a crosier-like form, as in *fig.* 3*a*. The cells

* Trans. Microscop. Society, vol. ii.

† Mr. Poulton has specimens of the shells, and the bodies of the animals deprived of the shell, mounted for the microscope.

are filled with a porous testaceous tissue, as shown in *figs.* 3 *b*, 3 *c*: which also illustrate the foraminiferous character of the shells in this class of animals; for both the external testaceous covering, and the septa of the cells, exhibit perforations.*



LIGN. 112. SPIROLINITES IN FLINT.

Chalk. Sussex.

(*By the late Marquis of Northampton.*)

The specimens are only sections of the shells imbedded in flint, and seen as opaque objects with a lens of moderate power. The small figures denote the size of the originals.

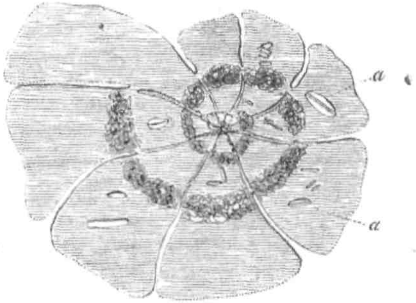
SPIROLINA. *Lign.* 112.—The general form resembles that of Lituola: the young shell being a discoidal, involute, and

* The perforations are omitted, by mistake, in the figure of the adult shell, *fig.* 3 *a*.

becoming produced by age; but the internal structure is different; the cells are simple cavities.

The chalk and flints of Sussex abound in these crosier-like shells, whose existence in the cretaceous rocks was first made known by my deeply lamented friend, the late Marquis of Northampton. The annexed lignograph, from drawings by his lordship, shows the form and structure as displayed by sections in fractured flints. Four species were named by Lord Northampton (see *Wond.* p. 325); but it is doubtful whether all the specimens belong to more than one species; the apparent diversity of structure may arise simply from the different planes in which the sections happen to have been made.

GLOBIGERINA. *Lign.* 109, *fig.* 1.—The shell is turbinated, the cells are spheroidal, and the last, or terminal one, has a semilunar aperture at the umbilical angle. Several fossil species abound in the Chalk and in the tertiary deposits; and many living species swarm in our seas.



LIGN. 113. NONIONINA GERMANICA, × 290.

A recent specimen of the body of the animal; the shell removed by acids.

From the North Sea, Cuxhaven. (*M. Ehrenberg.*)

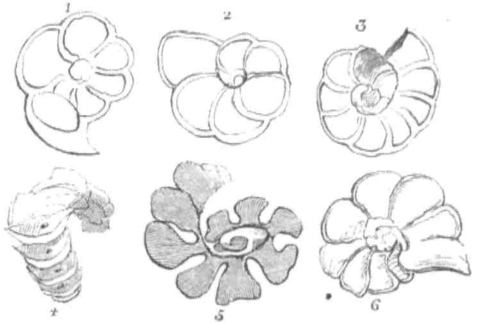
a, a.—Naviculæ and other organisms in the segments of the animal.

NONIONINA.—*Lign.* 113.—A nautiloid shell, with simple cells; the last cell has a single narrow aperture placed trans-

versely over the dorsal aspect of the spire. One species occurs in the chalk formation of Germany; several in tertiary deposits, and in the existing seas.

The figure, *Lign.* 113, represents the body of the animal deprived of its shell, to illustrate the nature of certain fossils from the Chalk.

ROTALIA. *Lign.* 114.—The shell, though nautiloid in its contour, is regularly turbinated, the cells not globular; the



LIGN. 114. FORAMINIFERA IN CHALK AND FLINT. × ×.

(*Seen by transmitted light.*)

Figs. 1, 2, 3, 6.—Different forms of ROTALIA.
2.—Resembles the recent ROTALIA STIGMA; Ehrenberg; from the North Sea, near Cuxhaven.
4.—Portion of a NAUTILUS, showing five chambers, partially separated, each pierced by the siphunculus: in Flint, from Ireland.
5.—The BODY OF A ROTALIA, in Flint; the shell is not apparent.

last cell has a central, semilunar, transverse, aperture. There are fifty fossil species. The Rotaliæ appear in the Lias, Oolite, and Chalk, in immense numbers, and swarm in the present seas.

ROSALINA. *Lign.* 109, *fig.* 5.—The shell is depressed; the spire apparent on one side; the aperture is a prolonged

slit extending from one cell to another, and opening on the umbilicus; that is, on the side opposite to the spire. There are eighteen fossil, and many recent species of this genus.

TEXTULARIA. *Lign.* 109.—This, and the following genus, belong to that order of Foraminifera in which the segments or cells are arranged in two or three distinct axes (*ante*, p. 342), and by their gradual increase give rise to an elongated conical but not spiral shell, which in its general outline resembles that of certain gasteropoda, but is easily distinguished by its internal structure. The shell is conical, compressed, formed of alternate cells, with a transverse aperture placed on the inner side. Upwards of thirty fossil species are known. The Textulariæ are in great abundance in the cretaceous rocks; and, together with Rotaliæ and Rosalinæ, constitute a large proportion of the minute organisms of the secondary formations as well as of the present seas.

VERNEUILINA.—*Lign.* 109, *fig.* 3.—A turriculated shell, with a slit or aperture transverse to the axis of involution, and placed on the umbilicus. This genus, of which but one species is known, is peculiar to the cretaceous deposits.

STRATA COMPOSED OF FORAMINIFERA.—From this concise exposition of the characters of the genera that most frequently occur in a fossil state, we pass to the examination of the organic composition of those limestones which are in a great measure made up of the debris of Foraminiferæ. We will commence the investigation with that common substance, the *white chalk* of the South-East of England.

It has long been known that a large proportion of the purest white chalk consists of minute chambered shells,* and corals.

Mr. Lonsdale, some years since, first showed that by brushing chalk in water, and examining the sediment, shells,

* Often termed *Polythalamia*, meaning many chambers or cells.

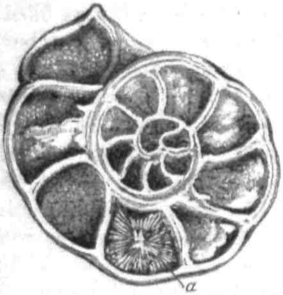
corals, and foraminifera might be obtained in abundance; but it was not at that time suspected that the residue of the detritus was almost entirely composed of distinct organic structures, so minute as to require high magnifying powers, and a peculiar mode of manipulation, for their detection and definition.

M. Ehrenberg demonstrated that even the fossils discovered by Mr. Lonsdale are colossal, in comparison with the *infinitesimal* structures of which the finer particles of the chalk consist; for one cubic inch of the limestone is found to contain upwards of a million of well-preserved animal organisms.

The chalk, therefore, is an aggregation of extremely minute fossils and inorganic particles. The yellow, soft, writing chalk of the North of Europe, according to M. Ehrenberg, is composed of about half its mass of organic remains; but in the chalk of the South of Europe, the fossils predominate. The amorphous atoms of the cretaceous limestone do not, as was formerly believed, arise from a precipitate of lime previously held in solution, but from the disintegration of the assembled organisms into more minute calcareous particles; and these have subsequently been reunited by a crystalline action, into regular, elliptical, granular, bodies.

M. Ehrenberg infers that the compact flint nodules have originated from an aggregation of pulverulent particles of siliceous organisms; and upon this hypothesis explains the absence of flint nodules, and the abundance of siliceous infusoria, in the beds of marl that alternate with the chalk in the south of Europe, and their presence in the chalk of northern Europe, in which the marls are wanting. In other words, he supposes, that in the former case the siliceous shells of the animalcules were spread abroad and deposited in layers or strata; and in the latter were aggregated into nodular masses. This opinion is not, however, supported by facts; for, though the animal origin of lime, flint, and iron,

as in the sketches *Lign.* 114, *ante* p. 351. If a chip or slice of flint, rendered transparent by immersion in oil of turpentine or Canada balsam, be viewed first with a low power, (1 inch object glass,) to discover a good specimen, and afterwards under a high magnifier, (a $\frac{1}{4}$ or an $\frac{1}{8}$ object glass,) the form of the shell and of the cells will be distinctly seen, as in *Lign.* 116. In this beautiful fossil Rotalia, the segments are as sharply defined as in a recent example: and one of the cells (*a*) is seen to be lined with quartz crystals.



LIGN. 116.

SECTION OF A ROTALIA IN FLINT.

(*Seen by transmitted light, and showing the chambers partially filled with mineral matter.*)

a. A cell lined with spar.

(× 250 *diameters.*)

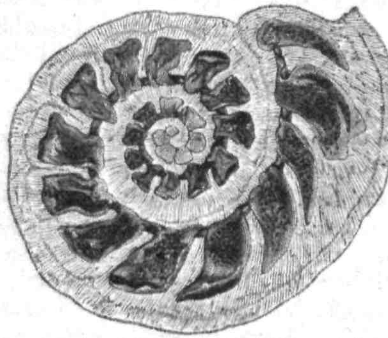
At first sight this fossil might be mistaken for a nautilus partially filled with spar; but the reader will remark that the septa, or partitions, have their convex surface towards the aperture; whereas in the shells of the Cephalopoda (*Nautilus, Ammonite,* &c.) the septa are concave anteriorly. In *Lign.* 114, *fig.* 4, a series of casts in flint of the septa of a young Nautilus is represented; by comparing it with the Rotaliæ in the same lignograph, *figs.* 2, 3, this distinction will be obvious. And here it may be necessary again to point out the essential character of the animal of the foraminifera, as distinguished from that of the cephalopoda with chambered shells. In the latter, the body of the mollusk only occupies the large outer chamber; the internal compartments are empty dwellings, which the animal has successively quitted in the progress of its growth, and with which it has no connexion except by the siphunculus. In

the Rotalia, and allied forms, the body of the animal is inclosed within the shells, and occupies every chamber contemporaneously at every stage : the cells are always filled by the segments of the body. Hence when the shell, which is calcareous, is dissolved in weak hydrochloric acid, the soft body is exposed, and seen to extend to the innermost chamber. The segments are connected by a membranous tube, which some naturalists regard as a common channel of communication between the several digestive sacs of which the body consists ; for minute diatomaceæ which the animal has swallowed, (according to Ehrenberg,) are seen within the membranous sacs ; as shown in *Lign.* 113, which represents the body of a Nonionina, deprived of its shell. The importance of obtaining a correct idea of this structure will presently appear.

When a recent Rotalia is immersed in dilute acid, the soft parts of the body, deprived of the shell, may be obtained entire ; they consist of a series of little bags or sacs, united by a tube. The constituent substance appears to be a tough membrane, and is generally of a rich brown or amber colour. The sacs are sometimes full of a granular substance, but are often empty and collapsed.

FOSSIL REMAINS OF THE SOFT PARTS OF FORAMINIFERA. *Lign.* 113.—When examining chalk* and flint under the microscope with the view of discovering the fossil bodies described by M. Ehrenberg, I observed that the cells of the Rotaliæ in flint were frequently occupied by a substance varying in colour from a light amber to a dark brown, and closely resembling in appearance the body of the recent foraminifer deprived of its shell. Under a high power, the folds of the membranous sacs and the connecting tube were apparent, and I felt convinced that the substance filling the cells was not inorganic, but the original animal tissues in

the state of molluskite.* In short, that the animal had become immersed and preserved in the fluid silex like the



LIGN. 117. ROTALIA IN FLINT, WITH THE FOSSILIZED BODY OF THE ANIMAL IN THE SHELL: *highly magnified.*

(*Seen by transmitted light.*)

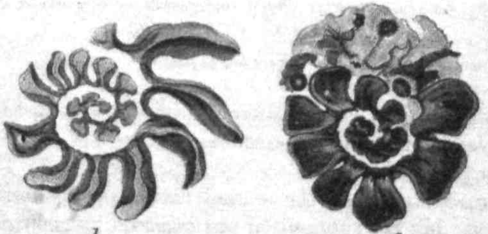
insects in amber. The appearance of the first discovered example of this kind is represented in *Lign.* 117.

In a paper read before the Geological Society in 1845,† I ventured to affirm the animal nature of the fossils in question; but the supposition was regarded by geologists as very startling and unsatisfactory; and as the specimens were enveloped in flint, the appearance was attributed to the infiltration of mineral matter of a different colour from the surrounding silex, into the empty chambers; a circum-

* *Molluskite:* a name by which I proposed to distinguish the carbonaceous substance resulting from the soft bodies of testaceous mollusca.

† Notes of a Microscopical Examination of the Chalk and Flint of the South-East of England, with Remarks on the Animalculites of certain Tertiary and Modern Deposits. Published in the Ann. Nat. Hist., Aug. 1845.

stance of frequent occurrence in Ammonites, Nautili, and even in the foraminifera; for the latter are often filled with chalk, flint, silicate of iron, crystal, &c. as in *Lign.* 116. In these instances, I conceive the shells were either empty when immersed in the fluid chalk or flint, or speedily became so by the decomposition of the soft parts of the animal. But in the fossils under consideration, I believe the live animal was suddenly enveloped, and hermetically sealed, as it were, in its shell, and that putrefaction was thus prevented. The uniformity in colour, and the structure of the substance in the cells, appeared to me incompatible with its assumed mineral origin, and I resolved to follow up the inquiry by an examination of Rotaliæ in chalk; in the hope that by dissolving the shell in acid (as in recent foraminifera), the body of the animal might be detected in an unmineralized state. After many fruitless attempts, several examples of



1 2

LIGN. 118. THE SOFT BODIES OF FORAMINIFERA; EXTRACTED FROM CHALK: *highly magnified.*

(*Viewed by transmitted light.*)

Fig. 1.—An exquisite example of the body of a ROTALIA; the sacs partially collapsed.

2.—Body of a ROTALIA; the sacs distended with a dark granular substance.

the soft bodies of Rotaliæ were obtained from the grey chalk of Dover, in an extraordinary state of preservation.*

* To Henry Deane, Esq. of Clapham Common, I am indebted for some of the most illustrative specimens hitherto obtained.

These marvellous relics were obtained by subjecting a few grains of the chalk to the action of weak hydrochloric acid, by which the calcareous earth and the shells it contained were dissolved; the residue, consisting of particles of quartz and green silicate of iron, and remains of the animal tissues, were placed, in the usual manner, in Canada balsam. Two exquisite specimens of the bodies of Rotaliæ thus obtained are figured in *Lign.* 118.*

In these fossils the sacs are generally more or less distended with a dark substance, as in *Lign.* 118, *fig.* 2: but in some, they are empty and collapsed in folds, just as membranous pouches would appear under similar conditions; as in the exquisite fossil, *Lign.* 118, *fig.* 1.

The sacs regularly diminish in size from the innermost to the outermost cell, and vary in number from fourteen to twenty-six; being more numerous than in the recent species of Rotaliæ that have come under my notice. In some instances small papillæ are seen on the outer surface of the integument; apparently the vestiges of the pseudopodia.†

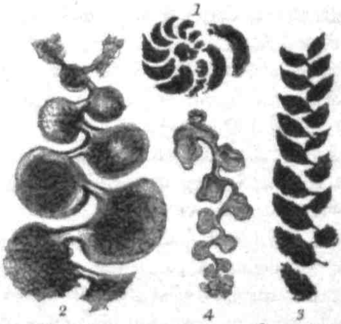
Not only is the form and general character of the animal substance preserved, but even its flexibility; for in one instance, the body, released by the solution of the chalk and shell, was uncoiled and pressed out, as shown in *Lign.* 119, *fig.* 4.

In one specimen, (figured in *Philos. Trans.* 1846, pl. xxi. fig. 10,) the membrane of the largest sacs is much corrugated, and disposed in numerous duplications, probably owing to the empty state of these segments, when immersed in the chalk; but the discoidal contour of the original is

* I communicated this discovery to the Royal Society. See Philos. Transactions, 1846, p. 465.

† Admirably as my excellent engraver, Mr. Lee, (of Prince's Square, Kennington,) has executed the lignograph, 118, I would refer the reader to the steel plate in Philos. Trans. 1846, pl. xxi. for figures of these marvellous fossils.

well preserved. This fossil so closely resembles the decalcified body of a recent Rotalia or Rosalina, that an eminent observer who saw it under the microscope at the meeting of the Royal Society, without knowing its history, concluded it to be the body of a recent animal. This extraordinary preservation of the soft delicate tissues of an animal of the cretaceous seas, invisible to the unassisted eye, through the



LIGN. 119. REMAINS OF FORAMINIFERA; IN CHALK AND FLINT.

(*Viewed by transmitted light; highly magnified.*)

Fig. 1.—Shell of a ROSALINA, filled with mineral matter; *in flint.*
2.—Soft parts of a TEXTULARIA; *in flint.*
3.—Cells of TEXTULARIA ELONGATA; filled with mineral matter; the shell not visible; *in flint.*
4.—The soft body of a ROTALIA, deprived of its shell, and partially uncoiled; obtained from Chalk. × 450 *diameters.*

incalculable ages that must have elapsed since the deposition of the chalk in which it was enshrined, is a fact as remarkable as the occurrence of the carcass of the Lena Mammoth, in the frozen soil of Siberia.

The soft parts of other foraminifera have been discovered in a similar state of preservation. A fine example of the body of a *Textularia*, in flint, is figured, *Lign.* 119, *fig.* 2.

The form and disposition of the segments in *Textularia*

elongata, is shown in *Lign.* 119, *fig.* 3. These cells are filled with inorganic matter. The shell of a Rosalina filled with an opaque mineral substance, forming casts of the cells, is represented in *Lign.* 119, *fig.* 1.

The preservation of the soft parts of foraminifera and of mollusks, in a fossil state, is a phenomenon of frequent occurrence, and no longer questioned by geologists, notwithstanding the scepticism with which my first announcement of the fact was received. Dr. Bailey, of West Point Military Academy, soon after the publication of my first paper, sent me specimens from the marls of New Jersey.

FORAMINIFEROUS LIMESTONES OF INDIA.—So much doubt was expressed as to the accuracy of my opinion respecting the nature of the fossil Rotaliæ, that its corroboration by observations on certain limestones in India, by H. J. Carter, Esq. Secretary of the Bombay Royal Asiatic Society, was as gratifying as unexpected. According to the researches of that gentleman, the south-east coast of Arabia is chiefly composed of two distinct limestone formations; the one averaging about 4,000 feet above the level of the sea, and the other 600 feet. The latter forms the desert of Akaf, and with the intervention of the mountains of Omân, which belong to the greater formation, passes up into the lower Sindh; while the former constitutes the high land of the coast, which, parting from the western border of the Desert of Akaf, extends nearly to Cape Aden.

The limestones of both these groups, or formations, consist chiefly of foraminifera; the largest forms being visible to the naked eye. Mr. Carter states that his attention was first directed to the organic composition of the Porebunder limestone, which is imported into Bombay for building, by small amber-coloured specks on the stone, that resembled the soft parts of foraminifera figured and described by me in the Philosophical Transactions. "On subjecting a portion of the limestone to the action of acid, I found them to be

what Dr. Mantell's observations had led me to expect, the actual remains of the animals, of exquisite beauty in form and symmetrical development. The minute kinds in the Porebunder stone do not average more than $\frac{1}{900}$ of an inch in diameter; and the composite forms are held together by thread-like attachments, which indicate the tubular communications that existed between them when living."*

FORAMINIFEROUS DEPOSIT AT CHARING. *Lign.* 109.—The little town of Charing, in Kent, has acquired a celebrity among those naturalists who are interested in the present inquiry, by the researches of William Harris, Esq. F.G.S. who some years since made known the existence of a remarkable deposit of chalk detritus, about one foot in thickness, which extends over the outcrop or exposed surface of the firestone in that locality.

This bed consists of a soft, whitish, tenacious clay, which, when immersed in water, is found to be largely composed of minute grains, that prove to be foraminifera. These shells belong to many species and genera; and are associated with the cases of entomostraceous crustaceans, spicula of sponges, &c. The organisms readily separate from the amorphous particles by washing, and specimens may be easily obtained as distinct and perfect as if recent. See *Lign.* 109, *ante*, p. 342. Intermingled with the cretaceous forms, are minute freshwater shells, apparently derived from a modern source.

The Charing deposit appears to have originated from the action of water on the unconsolidated chalk of the neighbouring Downs, before the surface of the hills was protected by a covering of vegetable soil.

Through the liberality of Mr. Harris, I have been able to examine an extensive series of the Charing Foraminifera; and Prof. Williamson has figured and described the principal

* "On the Existence of Beds of Foraminifera, Recent and Fossil, on the South-East coast of Arabia," by H. J. Carter, Esq.; Proceedings of the Bombay Royal Asiatic Society, 1848.

types in an interesting memoir in the Transactions of the Manchester Philos. Soc. vol. viii. 1847. As in most of the cretaceous strata, the prevailing species are referable to the genera Textularia, Rotalia, Rosalina, Cristellaria, Lagena,* &c. *There are numerous spicula of sponges, and needle-like* calcareous prisms, which are the detritus of the fibrous shells, called Inoceramus.

FORAMINIFERA OF THE OOLITE, LIAS, &c.—The occurrence of certain genera in particular rocks has been incidentally noticed in the previous descriptions, and it is needless to particularize any localities of the Oolite, Lias, and other secondary deposits. It must suffice to state that Dr. Carpenter, Prof. Williamson, Prof. Phillips, Mr. Sorby, Mr. Rupert Jones, and other able observers, have figured and described foraminifera from the strata between the Chalk and the Carboniferous formations: the report to be drawn up by the two first-named gentlemen for the British Association, will present a *resumé* of the British fossil genera and species.

It is deserving record, that no vestiges of foraminifera have been found in the Wealden strata; the fluviatile origin of those deposits renders it improbable that the remains of these marine organisms should occur in great numbers, yet from the estuary character of some of the beds, the presence of foraminifera might be expected.

FORAMINIFEROUS DEPOSITS OF THE UNITED STATES.—Dr. Bailey has made us familiar with the foraminiferous rocks of North America. The various memoirs on this class of fossil animalculites, and on the diatomaceæ (*ante*, p. 93), published in the American Journal of Science, and in the Smithsonian Transactions, attest the acumen, and unwearied spirit of research, of this able observer. Not only from the United States, but from numerous localities in

* This interesting type of Foraminifera is the subject of a Memoir by Prof. Williamson; Annals, Nat. Hist. 1848, vol. i.

Asia and Arabia, Dr. Bailey has transmitted me specimens of limestones containing foraminifera, chiefly of the genera Rotalia and Textularia.*

In the calcareous marls of the Upper Missouri river, extending nearly to the Rocky Mountains, similar fossils are met with.

In the interior of Florida, the white orbitoidal limestone is traversed by flint; and the calcareous and siliceous masses are full of microscopic foraminifera.†

Foraminifera of the Carboniferous Formations.—In the carboniferous limestones of England, the late Mr. Bowman, Prof. Tennant, and Mr. Darker, detected shells of foraminifera, apparently of the genus *Fusulina.*‡ Prof. Phillips mentions the occurrence of nautiloid foraminifera in the palæozoic limestones of Carrington Park, South Devon, and Yorkshire.§

Dr. Dale Owen is said to have obtained "well characterized polythalamia from the oolitic portion of the carboniferous (Pentremitic, *ante*, p. 298,) limestone of Indiana."‖ And M. de Verneuil discovered a species of Fusulina, in the Millstone grit of the coal formation of the Ohio.

But the most remarkable deposits of foraminifera in the palæozoic rocks, are those of Russia, described by Sir Roderick Murchison.¶ The upper beds of the Mountain limestone in the Lower Volga, consist of laminated calcareous shales, composed of an aggregation of shells of Fusulinæ. Bands of limestone, through a vertical extent of two hundred feet, are loaded with Fusulinæ; layers from five inches to five feet

* From Beyrout, Damascus, the Mount of Olives, Anti-Libanus.

† Smithsonian Contributions, vol. ii. p. 161.

‡ Edinburgh New Phil. Journal, vol. xxx. p. 44.

§ Proceedings of the Polytechnic Society of the West Riding of Yorkshire, 1845.

‖ American Journal of Science, vol. xlvi. note to p. 311.

¶ Geology of Russia in Europe, vol. i. p. 86. pl. i. fig. 1.

in thickness, consist of a pure white Fusulina limestone; the foraminifera are all of one species, the *Fusulina cylindrica.*

FORAMINIFEROUS LIMESTONE OF NEW ZEALAND.—"On the eastern coast of the Middle Island of New Zealand, to the north of Otago, strata of yellow and fawn-coloured limestone appear on the surface at Ototara, and continue to Kakaunui. This rock is generally friable and porous; it contains terebratulæ, spines and cases of echinoderms, pseudo-belemnites, teeth of sharks, &c. A microscopical examination shows it to be in a great part composed of an aggregation of very small polythalamia." * The specimens of the Ototara limestone received from my son, are very rich in minute corals and shells, and foraminifera of the European cretaceous type: species of Rotalia, Cristellaria, Globigerina, Textularia, Rosalina, Nodosaria, Dentalina, &c. Among them are two forms which occur at Charing; namely, *Rosalina Lorneiana, Lign.* 109, *fig.* 5, and *Textularia elongata*: of the latter a specimen in flint is figured, *Lign.* 119, *fig.* 3. The soft parts of Rotaliæ are preserved in the Ototara limestone, as in our chalk.

There are likewise, as at Charing, cases of Entomostracæ of the genera *Basidia* and *Cythereis.*†

The assemblage of fossil remains in the Ototara rock has decidedly a cretaceous aspect, but till the geological position of the strata in relation to the other formations of the Island is determined, it would be premature to regard these limestones as the equivalents in time of the Chalk formations of Europe.‡

TERTIARY FORAMINIFERA.—The marine tertiary deposits

* Notes on the Geological Structure of the Middle Island of New Zealand, by Walter Mantell, Esq. of Wellington. 1848.

† See Geol. Journal, vol. vi. p. 339. pl. xxix.

‡ A list of the Ototaran fossils collected by Mr. Walter Mantell, is given in Geol. Journal, vol. vi. p. 329.

which contain foraminifera in abundance, are so numerous, that it is unnecessary to particularize any. The sands of the Paris basin in some localities are so full of microscopic forms, that a cubic inch of the mass contains sixty thousand. The friable calcareous strata at Grignon are a loose aggregate of the shells of foraminifera and minute mollusks; and as the fossil shells from that locality are very common, and generally filled with débris, the student will have no difficulty in obtaining specimens for examination. The tertiary argillaceous deposits of England are less rich in foraminifera than the arenaceous; but the usual types occur in the London Clay, at Highgate, Clapham Common, Bracklesham Bay, &c. The Eocene marls of the United States are rich in foraminifera.

FORAMINIFERA OF THE FENS OF LINCOLNSHIRE AND CAMBRIDGESHIRE.—Though the alluvial deposits of the fen-districts are comparatively of modern date, yet the rich assemblage of foraminifera contained in the clay of certain districts is so interesting and instructive, that a brief notice of them must not be omitted. The foraminiferous character of the Lincolnshire alluvium was first made known to me by specimens from Bolton, sent me by Professor Williamson; and their extension over a wide area in Cambridgeshire, by a liberal supply from Mr. Smith, of March. The bed that abounds in these shells, is about seven feet beneath the surface, and consists of a fine sea sand combined with carbonaceous and argillaceous matter. By washing about a gallon of this earth in water, an ounce of polythalamia and organic detritus may be obtained. The perfect shells are as fresh as if just dredged up from the sea; the soft parts—the membranous segments held together by their tubular connexion—in many instances remaining in the shell; these parts may be obtained by the solution of the shell in acid. When the Rotaliæ are rendered transparent by immersion in Canada balsam, their appearance by transmitted light is

identical with that exhibited by the fossil specimens; and if viewed by reflected light, the body may be seen occupying all the cells of the shell; but the segments are somewhat collapsed; evidently from the shrinking of the animal tissues after death.*

The organisms of the Lincolnshire alluvium have been thoroughly investigated by Prof. Williamson; they comprise many species and genera, of the usual types; as Rotaliæ, Rosalinæ, Polystomellæ, Textulariæ, Lagenæ, Nodosariæ, &c. It is remarkable, that though a marine estuary deposit, no vestiges of diatomaceæ have been observed.

The bed so rich in foraminifera, extends west and south-west of the Wash. Mr. Smith sent me a mass of sandy clay, from a well sunk in the town of March, to the depth of twenty-five feet, that was loaded with these beautiful organisms.†

RECENT FORAMINIFEROUS DEPOSIT AT BRIGHTON.—An interesting fact connected with the phenomena under review is deserving record. The presence of the fossils of an older formation, in strata, subsequently deposited, and in part composed of the detritus of the rocks whence the organic remains were derived, is not uncommon: such fossils are termed by the French geologists "*fossiles remaniés.*" The nature of these re-deposited fossils is generally obvious; either by the waterworn condition of shells, bones, &c. or from their containing particles of their parent bed; or if casts, from their mineral composition. Thus in the chalk of St. Catherine's Mount, near Rouen, there are numerous casts of Ammonites, Scaphites, and other shells, composed

* Two specimens are figured in my notice of fossil Foraminifera. Phil. Trans. p. iv. for 1846, pl. xxi. figs. 13, 14.

† The reader interested in these inquiries should peruse the highly interesting Memoir by Prof. Williamson, "On some Microscopical Objects found in the Mud of the Levant, and other Deposits." Manchester Phil. Trans. vol. viii.

of marl full of particles of greensand. These have evidently been washed out of the preceding cretaceous beds of firestone or glauconite; and re-deposited in the chalk strata in which they are now imbedded.*

Along the sea-shore, to the east of Brighton, there is a bank of sand and calcareous mud, the detritus of the neighbouring cliffs, in the progress of formation; and in this sediment Mr. Reginald Mantell discovered *recent* Rotaliæ, Nodosariæ, &c., with frustules of Bacillariæ, Coscinodisci, Naviculæ, and other diatomaceæ; associated with cretaceous polythalamia washed out of the chalk.† The difference in the aspect of the recent and fossil organisms was so evident, as to leave no doubt of the correctness of this interpretation. Here, then, at the present moment, a deposit is going on, whose organic contents consist of an assemblage of species of living animalcules of our seas, with the fossil forms of the ancient chalk ocean; in like manner as in the bed of the Nile, the Nummulites of the tertiary rocks are being imbedded with the existing mollusks and desmidiæ of that river (*ante*, p. 345).

Geological distribution of the Foraminifera.—According to the observations of M. D'Orbigny, the first appearance of the tribes of minute beings which have played so important a part in the elaboration of materials for the formation of the sedimentary rocks of the secondary and tertiary ages, and are at this moment invisible but powerful agents in the accumulation of calcareous sediments at the bottom of the sea, was in the Carboniferous epoch, and by a single type, the *Fusulina* (*ante*, p. 346). I believe no certain evidence of the occurrence of Foraminifera in Silurian or Devonian deposits has been obtained.

M. D'Orbigny gives the following summary of the distribution of the known fossil and recent species:—

* M. D'Orbigny.

† See *ante*, p. 99.

	GENERA.	SPECIES.
Carboniferous System . .	1	1
Jurassic	5	20
Cretaceous	34	280
Tertiary	56	460
Living in the present Seas .	68	1000

Of the recent species, 575 inhabit the Tropics.
—— 350 —— Temperate zones.
—— 75 —— Cold regions.

The above statistical view was published six years ago; but the great activity of research that has since prevailed, has largely augmented the known number both of fossil and recent forms. M. D'Orbigny's recent Tables* give for the Jurassic or Oolite 10 genera; Cretaceous, 38 genera; Tertiary, 60 genera; but this estimate must be far too low.

I have thus endeavoured to convey a general idea of the highly important results obtained by the microscopical investigation of the minute organisms that enter so largely into the composition of many of the fossiliferous deposits.

Without the aid of the most perfect optical instruments which modern science and art have produced, even the existence of many of these structures could not have been demonstrated; and we cannot doubt, that were the powers of the microscope increased, the fossil remains of beings still more minute would be detected; and that rocks and strata which now appear to consist of amorphous particles of lime, of silex, and of iron, would prove to be the aggregated skeletons of animals, yet more infinitesimal than those which have formed the subject of our contemplations. How strikingly illustrative are these phenomena of the pro-

found remark of the illustrious Galileo—"*La nature fait beaucoup avec peu, et ses opérations sont toutes également merveilleuses.*"

INSTRUCTIONS FOR THE MICROSCOPICAL EXAMINATION OF CHALK, FLINT, AND OTHER ROCKS.

CHALK.—The following method is that recommended by M. Ehrenberg. Place a drop of water upon a plate of thin glass, and put into it as much scraped chalk as will cover the fine point of a knife, spreading it out, and leaving it to rest a few seconds; then withdraw the finest particles which are suspended in the water, together with most of the liquid, and let the remainder become perfectly dry. Cover this dried spot of chalk with Canada balsam (the turpentine of *Abies balsamea*), and hold the plate of glass over the flame of a lamp, until the balsam becomes slightly fluid, without froth or air-bubbles; it should be maintained in this position (the glass being kept as hot as the finger will bear) for a few minutes, until the balsam is found to have thoroughly permeated the substance to be examined. It is preferable to place a piece of very thin glass upon the balsam, and gently press it down, and allow it to remain. The best flatted crown-glass should be used for placing the chalk or other objects on. It is convenient to have the slips of glass of one size, or the specimens will require different boxes for their reception; three inches by one inch is that usually employed.

These objects require to be viewed with a power magnifying three hundred times linear, that is, in diameter; and if the process has been properly conducted, it will be seen that the chalk is chiefly composed of well-preserved organisms. In these preparations the cells of the foraminifera appear at first black, with a white central spot; this is caused by the air contained in those cavities, for air-bubbles always appear as black annular bodies; by degrees the balsam

penetrates into all the single cells, the black rings of the air vesicles disappear, and the structure of the original is beautifully displayed.*

SOFT PART OF ROTALIÆ IN CHALK.—The manner in which I obtained the unmineralized soft bodies of foraminifera from chalk has already been mentioned (*ante*, p. 360); but it may be useful to offer a few additional suggestions; for such fossil remains are not easily extracted. Many experienced microscopical observers have not succeeded in obtaining one good specimen; but others have been more fortunate, or persevering.

In several glass test-tubes, (the more the greater chance of success,) put a few grains of chalk powder: pour the tube half full of diluted hydrochloric (muriatic) acid—about ten parts water to one of acid—agitate, and set the mixture by: when all action has ceased add one or two drops of undiluted acid to each tube, and repeat the process at due intervals till all the calcareous matter is dissolved. Pour off the fluid, substitute distilled water, agitate, and then let the sediment subside. The residue will consist of atoms of quartz and other insoluble mineral matter, and animal tissue, if there be any. Then, with a camel-hair pencil, place a small portion of the sediment on a glass slide, and when dry cover it with Canada balsam, and treat it as above directed. Among a dozen slides thus mounted, there will probably be two or more good examples of the body, or detached membranous segments of Rotaliæ or Textulariæ, like those figured in *Lign.* 118.

CALCAREOUS SANDSTONES AND MARLS.—These substances may be examined by the same process; but if of loose texture, Dr. Bailey recommends that some of the sandy

* Specimens of chalk, flint, and other rocks for examination; or specimens prepared on slides, may be obtained of the microscopic artists, named in the Appendix.

powder should be spread very *thinly* on a plate of glass, with or without water, and by the aid of a lens of moderate power the roundish grains should be selected and picked up with fine forceps, or the point of a needle, and transferred to another piece of glass, having on one spot a thin coat of Canada balsam. This should be gently heated over a spirit lamp, when the balsam will penetrate the grains, and render them transparent; by this process the minutest shells, &c. may be detected. For a hasty exploration, the dust may be rendered sufficiently transparent by a drop or two of oil of turpentine.

Sandy calcareous marls may be examined by diffusing a few grains in water in a wine-glass, the lighter portions will be suspended in the fluid, and may be placed on glass, and when dry prepared with Canada balsam in the usual manner.

FLINT.—Flint, and other siliceous stones, require to be chipped into very thin fragments, and immersed in oil of turpentine. A clear, translucent flint should be selected, from which fragments may be shattered off by smart blows of a hammer, over a sheet of white paper: the most transparent flakes are to be selected, and these should be put in oil of turpentine, in a wide-mouth glass bottle. Take out the pieces for examination with forceps, and inspect them as transparent objects, by transmitted light. When good specimens are discovered, mount them in Canada balsam.

It is hazardous to entrust such fossils to the lapidaries; an interesting group of twenty spiniferites was reduced to ten, by one of our best workmen, in whose hands it was placed for polishing, with the view of rendering it more transparent.

come within the scope of our inquiries: yet it is possible that the soft parts even of these perishable structures may have left some trace, or that markings of their integument on the silt or mud may be preserved;* and I would recommend the student to search for such indications on the rippled surface of clays and sandstones.

b. The BRACHIOPODA (*arm-feet*) have two long spiral fleshy arms, or *brachia*, developed from the sides of the alimentary orifice, are enclosed in bivalve shells, and respire by means of their vascular skin, or mantle. They have not the power of locomotion, but are fixed by a peduncle to other bodies.

c. The LAMELLIBRANCHIA (*plated gills*) have also bivalve shells, but their respiration is effected by gills composed of vascular membrane disposed in plates, and attached to the mantle; the *beard* of the Oyster is the branchial or respiratory apparatus of that animal. These bivalve Mollusca are subdivided into those which close their shells by one adductor muscle, hence called *monomyaria*, as the Oyster; and those which have two muscles, *dimyaria*, as the Cockle. As the impressions left on the shells, by the attachment of these adductor muscles, and by the margin of the mantle, are found as perfect in the fossil as in the recent, they constitute important distinctive characters.

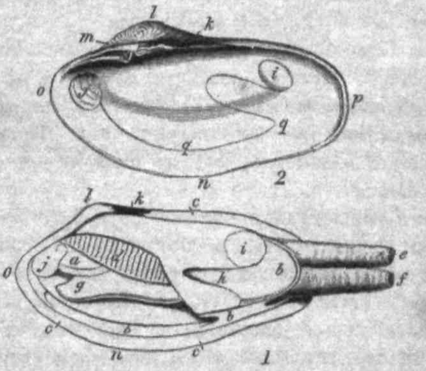
Dr. Gray's definition of the respective parts of univalve and bivalve shells is at once clear, concise, and natural, being conformable to the structure of the body of the enclosed mollusk.

The *front* of the shell is the part which covers the head of the animal; the back of the shell is the part which covers the tail; the left and right sides correspond with the same parts of the mollusk.

In univalves, the apex of the shelly cone whether it be

* The *Ischadites Königi* of the Ludlow rock was supposed to resemble *Boltenia*, a pedunculated Ascidian.

simply conical or spiral (except in Patella) is over the hinder part of the animal: when the shell is placed on its mouth with the apex towards the observer, the parts of the shell correspond with the position of the person looking at it.



LIGN. 121. ILLUSTRATION OF FOSSIL BIVALVE SHELLS; *nat.*

PETRICOLA PATAGONICA. *D'Orb.*

Interior of right valve, and the same valve with the animal as seen on the removal of the left valve.

a. Labial Palpi.
b. Mantle.
c. Margin of shell.
d. Branchiæ.
e. Anal siphon.
f. Branchial siphon.
g. Foot.
h. Retractor muscle of siphons.
i. Posterior adductor.
j. Anterior adductor.
k. Ligament.
l. Umbo.
m. Lunule.
n. Base, or ventral margin.
o. Anterior side.
p. Posterior side.
q. Pallial line.

(The length of the shell is estimated from *o* to *p*, its breadth from *l* to *n*.)

In bivalves (*Lign.* 121) the ligament is always on the dorsal surface of the animal, and the mouth in front of the apex or umbo of the valves, before the ligament. A bivalve placed with the hinge side uppermost and the ligament

towards the observer is in the same relative position as the person looking at it; viz. the HEAD in front, and the right and left valves in their natural relations. The length of the shell is therefore from the front to the back of the animal: the width or transverse diameter is from the umbo to the margin. Much confusion has arisen from many conchologists having described the length and width of a shell diametrically opposite to the proper position of its inhabitant.

II. The ENCEPHALOUS MOLLUSCA.—These possess a head, with feelers or soft tentacula, eyes, and a mouth with jaws; they are arranged in classes, according to the modification of their locomotive organs; for, with but few exceptions, they are free animals, and can crawl, climb, or swim. Their shells are, for the most part, composed of one piece, or valve, hence they are termed *Univalves*. In some genera the shell is a simple cavity, spirally disposed, as in the Snail; in others, it is conical, consisting of one or many pieces, as in the *Limpet* and *Chiton*. In the Cephalopoda it is internally divided into cells, or chambers, as, for example, in the Nautilus.

The Encephalous Mollusca are subdivided into the following classes; viz.—

a. PTEROPODA (*wing-feet*).—In these the organs of progression are two wing-like muscular expansions, proceeding from the sides of the neck, by which they can swim and float in the open sea: all the species are of small size.

b. GASTEROPODA (*feet under the body*).—These crawl by means of a muscular disk, or foot, which is attached to the under-part of the body; most of the species are marine, but some are terrestrial, and others inhabit fresh-water. They are very widely distributed; the garden snail is a familiar instance of a terrestrial Gasteropod.

c. CEPHALOPODA (*feet around the head*).—The mollusca of

this order have powerful muscular arms, or tentacula, which surround the head, or upper part of the body; some genera have no shell, but possess an internal skeleton, as the recent Sepiadæ and the fossil Belemnitidæ. Most of the testaceous Cephalopoda have a discoidal, univalve shell, which is divided internally by septa or partitions; as the Nautilus.

In many univalves the aperture or opening is entire, that is, without any notch or groove; in others it is notched or extended into a canal, or siphon, and this character has relation to the respiratory organs: thus the Gasteropods, in which the water is conducted to the interior by a muscular tube, or siphon, have the margin of the aperture of the shell channelled; as in the Whelk, or *Buccinum*. Many of the land and fresh-water species have entire openings, and are, for the most part, herbivorous; while the greater number of the marine univalves have the aperture indented or notched, and are carnivorous.* Some of these mollusca, too, have a retractile proboscis, armed with minute teeth, by which they can rasp or bore into the shells of the species on which they prey. There are some exceptions to the above rules, but the prevalence of the characters specified afford pretty certain indications of the fluviatile or marine nature of the originals. The application of these data to geological investigations will be considered hereafter.

In the generic distinctions of the simple univalves, the form of the mouth is an important character; while in the bivalves, the configuration of the hinge affords an equally convenient aid for their classification.

* The form of the aperture does not necessarily indicate fresh-water genera. *Melanopsis, Pirena,* and most of the *Melaniæ* have a channelled or notched aperture. Fresh-water univalves frequently have the spire corroded; in a fossil state they can only be determined [to be fresh-water species] by their analogy to recent genera and sub-genera.—*Note by Mr. Woodward.*

Some tribes of testaceous mollusca are exclusively marine; many are restricted to the brackish water of estuaries; others live only in fresh-water; and some on the land. Their geographical distribution is alike various: certain groups inhabit deep water only, and are provided with means by which they can maintain themselves near the surface of the ocean, far away from any shore; while others are littoral, that is, live in the shallows along the sea-shores. Many exist in quiet, others in turbulent waters; some are gregarious, like the oyster; while others occur singly, or in groups. The vertical range, that is, the relative depths in which the mollusca live in the sea, is also strictly defined; certain genera being, in a great measure, restricted to moderate depths, others to a few fathoms, and many to the profound abysses of the ocean, which neither the dredge nor the plummet can reach. All these varieties of condition are more or less strongly impressed on the shells, which may be considered as external skeletons;* and the accomplished conchologist is enabled, by certain characters, to determine the nature of the animals which inhabited them, and the physical conditions in which they were placed.†

The number of living species of mollusca known to naturalists, not including the shell-less genera, exceeds twelve

* In equivalve bivalves the animal lives in an upright position. In inequivalves, *i. e.* one large and one small valve, the animal lies on its side. The situation of bivalve shells, as oysters, should therefore be noticed, for if they lie on their concave shell, with the flat valve uppermost, it is evident they were overwhelmed in their native bed and in a living state; if they lie indiscriminately on either valve, they were probably dead shells and overwhelmed in that state. If the pallial imprint is notched by a sinus, it shows the presence and size of the tubes of the mantle. Whether there be one or two muscular impressions is of far less importance.

† For an extended notice of the geographical distribution of testacea, see Prof. Edward Forbes, British Marine Zoology, Part I. p. 141.

thousand; and almost every day is adding new species, for scarcely a vessel arrives from distant seas without enriching the stores of the conchologist. The numerous genera into which they are divided by systematists, and the constant changes effected in arrangement and nomenclature by every writer on the subject, render it difficult if not impossible to present the reader with any satisfactory epitome of modern conchology.

I must restrict myself to a brief account of some of the *most common genera that occur in the British strata*; and shall dwell more particularly on those species which prevail in the secondary formations, because they present the most important deviations from the recent types that are familiar to the general observer; by this means, and by reference to figures in standard works, the collector will, I trust, be enabled to identify the fossil shells which may most frequently come under his notice in the course of his geological rambles.

FOSSIL BIVALVE SHELLS; INCLUDING THE BRACHIOPODA AND LAMELLIBRANCHIA.

Although in the modern Tertiary strata, as the Crag, and in the arenaceous beds of the Eocene formations, shells are generally found in so perfect a state, that no caution or knowledge is requisite for their collection, yet a few preliminary remarks are necessary to point out certain conditions in which the remains of mollusca, or evidence of their existence, occur in the mineral kingdom, and particularly in the older fossiliferous rocks. Shells are found in the strata in the three following states:—

1stly. Shells in which the constituent substance has undergone but little change. Many of the specimens in the

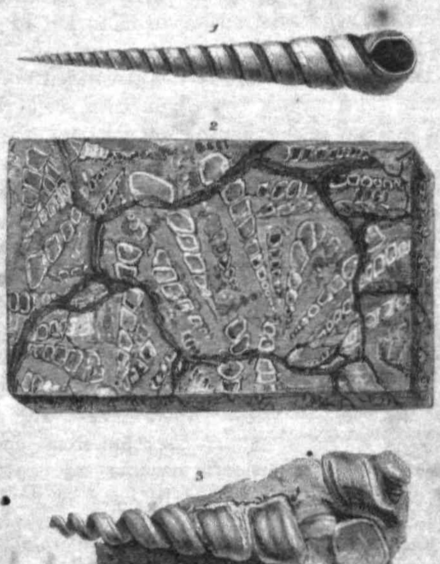
sands of the Crag in Norfolk and Suffolk, and in the Eocene beds at Grignon, near Paris, and the Pliocene of Palermo, in Sicily, are as perfect as if collected from the sea-shore, having suffered no loss but that of colour. In some instances, even the varied markings on the surface remain; but in general the shells are bleached, or have a ferruginous stain.

2dly. The form preserved, but the constituent substance mineralized. This state is very common in shells that are imbedded in hard rock, whatever may be the age of the deposit. In calcareous strata the testaceous substance is generally transmuted into calcareous spar, as in most of the specimens from the chalk, oolite, mountain limestone, &c. In sands abounding in silex, the shell is changed into flint, as in the exquisite fossils from the Green Sand of Blackdown, Devonshire; in deposits permeated with sulphuret of iron, the shells are often metamorphosed into pyrites, as in the Ammonites in the Lias, Galt, &c.

3dly. In the state of *casts* and *impressions*. Although in loose sand the shells are either empty, or filled with detritus easily removable by washing; in clay, limestone, and sandstone, the cavities are generally occupied by consolidated materials, which had entered when in a soft or fluid state; and frequently the substance of the shell has disappeared, and the stony cast of the interior alone remains. In many instances, the spaces left by the dissolution of the shells are filled with spar, or the casts are closely invested by the surrounding stone, from long-continued superincumbent pressure while the matrix was in a plastic state; and in such cases the casts are often distorted and flattened. But the vacancy is occasionally empty, and on its walls is found an impress of the external surface of the shell, with all the lines and ornaments of the original as sharp as if cast in plaster of Paris.

The specimen, *Lign.* 122, *fig.* 2, from the tertiary strata at Bracklesham Bay, Sussex, is a polished slice of indurated

argillaceous limestone, from a septarium (*nodule divided by fissures*), abounding in spiral univalve shells, called *Turritellæ*. *Fig.* 1 is a perfect shell of the same species, extracted



LIGN. 122. TURRITELLÆ, FROM BRACKLESHAM, SUSSEX. *Tert.*

Fig. 1.—TURRITELLA CONOIDEA; the perfect shell: *nat.*
2.—SEPTARIUM, with TURRITELLÆ; a polished slab: ½ *nat.*
3.—A cast of one of the shells, in calcareous spar: *nat.*

from soft clay; and *fig.* 3, a cast in calcareous spar, obtained from the septarium. In the polished slab, *fig.* 2, sections of numerous shells are seen. The dark partitions,

or septa, are veins of spar, which occupy interstices that have been formed in the clay-nodule by shrinking; and if the specimen be closely examined, the shells will be found split across and displaced by the fissures; thus presenting an interesting illustration of the *faults*, or dislocations, of the strata, so familiar to the geological observer. In the present instance, the lines on the exterior of the shell do not materially differ from those on the interior, and, consequently, the cast, *fig.* 3, and the shell, *fig.* 1, resemble each other; but in many species there is a striking contrast between the outer and inner surfaces, the external aspect being strongly ornamented, while the internal is smooth; the cast, therefore, in such examples, so little resembles the shell, that an inexperienced collector may readily suppose it belongs to a different species. The bivalve called *Trigonia*, *Lign.* 127, *figs.* 1, 2, is an instance of this contrast.

The polished slab of the Septarium, *Lign.* 122, *fig.* 2, demonstrates another condition of fossil shells—that of a compact argillaceous limestone—and entire beds of marble are composed of an aggregation of this kind, formed of shells and other animal exuviæ, consolidated by mineral infiltrations. In the older secondary strata this state prevails; and the beautiful markings of many valuable marbles, are merely sections of the enclosed shells. But this process is not restricted to the deposits of ancient date; at the present moment the same operation is silently but constantly going on in our seas, and an examination of the specimen, *Lign.* 123, will afford an exemplification of the manner in which these shelly limestones are produced.

We have here a solid mass of stone, composed of several recent species of shells, corals, &c. It is a fragment of a large block, dredged up from the British Channel, off Brighton. Similar masses have been obtained at different soundings along this part of the Sussex coast; and in some [illegible]

mussels, whelks, &c. enter into the composition of the consolidated rock. The shelly and coralline limestones and sandstones, so abundant in the ancient strata of England

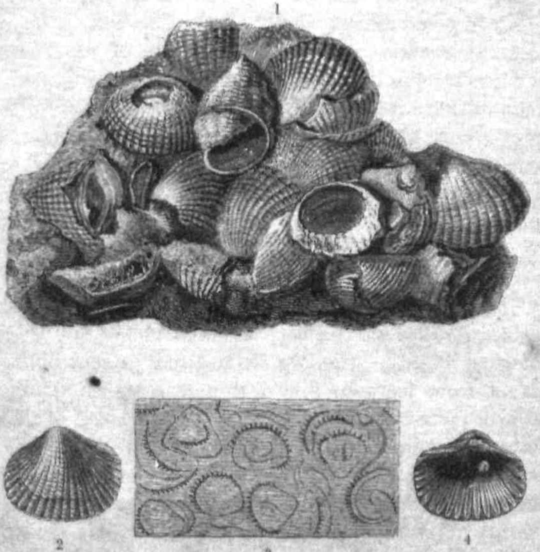
LIGN. 123. SHELL-CONGLOMERATE; NOW FORMING IN THE BRITISH CHANNEL.

Dredged off Brighton.

Fig. 1.—An Aggregation of Shells and Corals; the interstices are filled up with sand, and the mass is consolidated by an infiltration of carbonate of lime.
2.—TROCHUS ZIZIPHINUS; extricated from the mass with the following:
3.—PECTEN OPERCULARIS.
4.—SERPULA.
5.—Portion of a CELLEPORA; magnified.
6.—SABELLA.

have been formed in a similar manner; and when the modern conglomerate of Brighton shall have been permeated with crystalline matter, and subjected to great pressure by

superincumbent deposits, through countless centuries, and at length be elevated above the waters, it will constitute beds of shell-marble, in some mountain range, and become an interesting, perhaps the only memento, of the races of



LIGN. 124. SHELL-LIMESTONE; FROM THE MOUTH OF THE THAMES.

Fig 1.—A mass of Cockle-shells and Whelks, consolidated into a *coarse limestone.*

2, 4.—One of the shells, CARDIUM EDULE, extracted from the block.

3.—A slice of the rock, polished, the markings on the surface being derived from sections of the shells.

mollusca and polypiaria of the present seas, when all record and traces of Great Britain and its inhabitants shall be destroyed.

Off the Kentish coast, near the mouth of the Thames, a

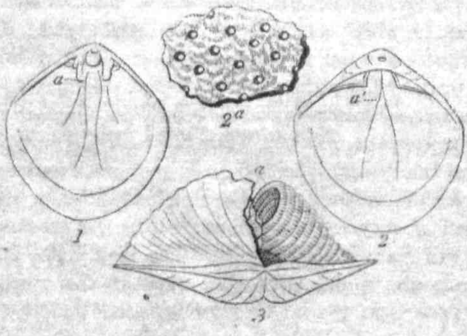
bank of consolidated shells, chiefly of one species, is in the progress of formation, from which blocks may be obtained of great firmness and solidity (*Lign.* 124); these, when cut and polished (*fig.* 3), display a variety of markings, produced by the sections of the shells. Extensive shoals of loose shells, composed almost wholly of the *Cardium edule*, exist in several localities, near the embouchure of the Thames; and these are continually shifting with the changes of the wind and tide; it is only in a few places that consolidated blocks occur, like that of which a fragment is figured in *Lign.* 124. These examples of shelly limestones and sandstones now in progress of formation will familiarize the student with the nature and origin of those ancient deposits of a similar character, which contain extinct species and genera of mollusca.

"The vast deposits of fluviatile shells which exist in Florida, at Picolata, Volusia, and Enterprize are of great geological interest. The two latter places present bluffs and hills of from forty to fifty feet in height, extending half a mile or more from the river, that are composed of scarcely anything but well-preserved shells of *Paludina vivipara, Ampullaria depressa*, some undetermined species of *Unio, Helix septemvolvis, Melania*, and a few others. There is but a scanty mixture of earth, and the shells are clean, and look as if they had been washed ashore after the death of their inhabitants. In some places the beds are sandy, and are hardening into a calcareous shelly sandstone. In one such bed the superficial stratum furnished a few bones of turtles and undetermined fragments, the bones of some large vertebrate animal. This is, I believe, the locality where Count Pourtalés collected human bones in a recent sandstone. . . . . . . No microscopical forms were detected in these beds after the most careful search." *

* Dr. J. W. Bailey, in Smithsonian Contributions, vol. ii. Article viii. p. 23.

when highly magnified, is shown *fig.* 2[a], *Lign.* 126.* The Rhynchonellæ (as *Lign.* 125, *figs.* 1, 2,) do not possess this organization.

Several species of Terebratula are found both living and fossil, *e. g. Terebratula vitrea*, living in the Mediterranean, fossil in Sicily,—*T. caput serpentis*, recent in the British seas, fossil in the Crag,—and *T. lenticularis*, both recent and fossil in New Zealand.



LIGN. 126. TEREBRATULA AND SPIRIFER.

Fig. 1 and 2.—Upper and under valve of TEREBRATULA CARNEA. *Chalk; Lewes: a, a*, remains of the calcareous support of the *brachia*.

2[a].—Portion of the shell of *Terebratula carnea*, magnified to exhibit the perforations.

3.—SPIRIFER TRIGONALIS, with part of the upper valve removed, to show one of the spiral processes. (*Min. Conch.*) *Mountain Limestone.*

SPIRIFER (*containing spiral processes*). *Lign.* 126.—In the Silurian, Devonian, and Carboniferous limestones there is a profusion of several genera of *Brachiopoda*, whose

* An interesting Memoir on the Microscopal Examination of Shells has recently been communicated to the Royal Society by Dr. Carpenter.

peculiar forms render them easily recognisable. Among these, the Spirifers are the most interesting, on account of their spiral calcareous processes, which in the recent state supported the ciliated *brachia*, being often preserved. A specimen, in which part of the upper valve of the shell has been removed, and one of the spires exposed, is figured *Lign.* 126, *fig.* 3. (*Wond.* pp. 735, 736).*

All these genera are extinct; they prevail in the oldest fossiliferous rocks, and gradually disappear as we ascend to the newer formations; the last trace of their existence is in the Lias, in which one species has been found. But the *Terebratulæ* abound in the Lias, Oolite, Chalk, &c., occur in the tertiary formations, and several living species inhabit the seas around Australia and New Zealand. (See *ante* p. 390.)

RHYNCHONELLA, *Fischer.* The "*plaited*" *Terebratulæ* differ from the typical species (*e. g.* T. australis, caput-serpentis, vitrea, &c.) more than even the Spirifers differ, and must be regarded as forming a distinct *family*, RHYNCHONELLIDÆ, which will include *Pentamerus.* The shell is not punctate; the arms are spiral, supported only at their origins by shelly processes; the larger valve is *beaked* acutely, and has a notch within the beak through which the pedicle passes; sometimes the notch is converted into a foramen, by two little plates, (*deltidium*,) as in *Terebratula.* The form of the Rhynchonellæ is tetrahedral. *Lign.* 125.

PENTAMERUS, *Ly.* p. 352.—With the Spirifers, and other Brachiopoda of the Silurian System, some bivalves which, in their general figure, resemble certain species of Terebratulæ, frequently occur. These shells differ in their internal structure from all other genera, in having a septum, or plate, by which their cavity is divided into four chambers; and in one valve the septum itself contains a cell, thus making five chambers, whence the name *Pentamerus* (*five-*

* See a Memoir on the Anatomy of the Brachiopoda, by Professor Owen. Zoological Trans. vol. i. p. 145, *et seq.*

celled). The casts of these shells often have fissures, produced by the decomposition of the septa; and occasionally these cavities are occupied by calcareous spar. Specimens of this kind commonly split into two parts, in one of which two, and in the other three, chambers may be detected; the fifth chamber is the canal of the peduncle. Four species are known, and all belong to the Silurian rocks.

ORTHIS, LEPTÆNA, and PRODUCTA form a third family, with horizontal spiral arms, unsupported by shelly processes. *Davidsonia* is a Leptæna *attached* by the ventral valve, and the only genus in this family which is fixed by *the shell itself*.

CALCEOLA. A genus of Brachiopoda; the shell of an inverted pyramidal form, the upper valve nearly flat; found in the Devonian strata of the Eifel, and in Devonshire.

CRANIA, *Ly. fig.* 205. These are small brachiopodous shells, attached to other bodies; very frequently to the Echinites of the chalk. The free valve is commonly wanting, but I have found specimens dispersed in the rock. In many of the quarries in Kent and Sussex, the helmet Echinites bear groups of these shells. *Ly. fig.* 13.

ORBICULA. This genus resembles Crania in form, the upper valve being like a limpet, whilst the attached valve is flat; it differs, however, from Crania in being horny and flexible, and is fixed to rocks on the bed of the sea, by a muscular pedicle passing out through a small fissure.

Species of Orbicula are found in strata of all ages, from the Lower Silurian to the Tertiary, and several are now living in tropical seas.

OBOLUS. *Eichwald.* In the Lower Silurian (*Obolite grit*) of Sweden and Russia, is a Lingula, with a hinge and a notch for the pedicle; it has not hitherto been found in Britain.

LINGULA. *Ly.* p. 353, *fig.* 412.—The Brachiopoda referred to this genus have a long peduncle, and their respiratory apparatus has no calcareous support; the recent species burrow in the sand, being usually inhabitants of shallow waters. The *Lingulæ* are readily distinguished from the Terebratulæ by their imperforate, equivalved shells. One species is found in the Aymestry limestone, and several have been collected from the Mountain limestone, Oolite, and Shanklin sand.

With reference to the species of Brachiopoda, particularly of the Terebratulæ, which inhabit the depths of the ocean, Professor Owen observes, that "both the respiration and nutrition of animals, which exist beneath a pressure of from sixty to ninety fathoms of sea-water, are subjects suggestive of interesting reflections, and lead us to contemplate with less surprise the great strength and complexity of some of the minutest parts of the frame of these diminutive creatures. In the unbroken stillness which pervades those abysses, the existence of these animals must depend on their power of exciting a perpetual current around them, in order to dissipate the water laden with their effete particles, and to bring within the reach of their prehensile organs the animalcules adapted for their sustenance."

HIPPURITES. This genus belongs to a group of fossil shells whose characters are somewhat problematical, some conchologists referring them to the ordinary bivalves, and others to the Brachiopoda. Although *Hippurites* have not been discovered in the British strata, I am induced to notice them in this place, in consequence of their great abundance in the Cretaceous deposits of the South of France, and in the Oolite of the Pyrenees; and also to illustrate the nature of a nearly related genus, *Spherulites*, of which one or more species occur in the Sussex Chalk.

The Hippurite is of an elongated conical form, and fixed

by its base; it has internally a deep lateral channel, formed by two obtuse longitudinal ridges. The base is sometimes partitioned off by transverse septa, forming cells or cavities, as in the Euomphalus. The aperture, or opening, is closed by an operculum, or upper valve. The substance of the shell is cellular, and very thick, and when fractured much resembles that of the lamelliferous corals: the laminæ are sometimes separated into cells, or cavities, like the Spondyli. These shells often attain considerable magnitude, and in certain districts of the Pyrenees, where they abound, are called "*petrified horns*" by the inhabitants. It is remarkable, that, while in the Chalk of the South of France, Spain, Portugal, and Greece shells of this genus so prevail, as to be considered the characteristic fossils of the formation, in the North of France they are very rare, and in England have not hitherto been discovered.*

FOSSIL SHELLS OF THE LAMELLIBRANCHIA.—These are bivalve shells, the animals of which differ from the preceding class, as we have already stated, in performing respiration by means of lamellated gills. The valves are united by a strong substance, termed the ligament, which, by its elasticity, admits of the shells being opened to a considerable extent; and they are closed by powerful, short, thick muscles, called adductors. The shells of some of the genera, as the Oyster and Scallop, have but one muscle, (*monomyaria*); others, as the Cockle, or Cardium, and Venus, have two, (*dimyaria*); and by these characters the class is arranged in two groups.

* As marking the rapid progress of Palæontology in this country, it may be noticed that the *only fossil* figured in the first edition of the Enclycopædia Britannica, in illustration of the article, "*Petrifaction*," is one of these supposed petrified horns, described by the Abbé Fortis.

MONOMYARIA : *Bivalve Shells, with one muscular impression.*

OSTREA, *Lign.* 120.—The Oyster is well known to possess no power of locomotion; it is attached to rocks, pebbles, and other bodies, and forms extensive beds, consisting of numerous individuals, of all sizes. There are many fossil species; the British strata yield between forty and fifty. In some localities, Oysters are found in thick beds, of great *extent, apparently on the spots they occupied when living.* One of the most interesting localities I am acquainted with, is Sundridge Park, near Bromley, in Kent, where a hard conglomerate, entirely made up of oyster-shells, and the shingle that formed their native bed, is quarried. This stone is much employed for ornamental rock-work, and several walls in and near Bromley are constructed of it: these display the fossils, some with the valves closed, others open, others detached, and the whole grouped as if artificially imbedded to expose the characters of the shells. These oyster-beds belong to the tertiary strata of the London basin; they extend to Plumstead, and other places in the vicinity; and in some localities, the oysters are associated with other bivalves, called *Pectunculi.* In the tertiary clays near Woolwich and Bexley, fossil oyster-shells abound. In the neighbourhood of Reading, in Berkshire, an extensive layer of fossil oysters occupies the same geological position, namely, the lowermost sands and clays of the London basin. Wherever the strata around London are perforated to a sufficient depth, this oyster-bed is reached. Very recently an Artesian well was bored at Hanwell, in Middlesex, and at the depth of two hundred and eighty feet this stratum of sand with oyster-shells was found. At Headley, near Reigate, in Surrey, there is a similar deposit. These oysters very closely resemble the edible species.

The White Chalk contains several species of Ostrea, but I believe no beds of these shells have been found in it; on the

contrary, the shells are diffused promiscuously through the strata. I have collected a few groups of from thirty to forty shells, evidently the young or fry of the species (*O. semiplana*) figured *Lign.* 120. This specimen is an interesting example of the petrifactive process which the mollusca have occasionally undergone; the soft parts of the oyster are transmuted into flint, and the shell is changed into carbonate of lime, having a crystalline structure. Both valves were perfect when discovered, but I chiselled off the greater part of one shell to expose the silicified body of the animal.

A small oyster, called *Ostrea vesicularis*, is a characteristic shell of the chalk; one valve is convex, the other flat; it is abundant in the Chalk of Norfolk, and also in the Firestone of some localities: it is figured *Ly.* p. 212. Another small species, having the margin plicated (*O. plicata*), is also frequent in the Chalk. A large shell, with the margins deeply indented by angular folds, resembling the recent cockscomb oyster, is abundant in the Chalk Marl and Firestone; particularly near Dover, and around Selbourne in Hampshire, where it attracted the notice of WHITE, by its resemblance to the living "Cockscomb Oyster" of the West Indies; it is named *Ostrea carinata*, and figured *Ly.* p. 212, *fig.* 204. One other species may be noticed, the *Ostrea deltoidea*, which has been found in every locality of the Kimmeridge Clay in England and France. It is a very flat species, and of a triangular form; the specific name is derived from a supposed resemblance to the Greek letter Δ, *delta*. I believe that in England no shells of this genus have been observed in strata older than the Lias.

GRYPHÆA. *Lign.* 127, *fig.* 6.—The shells to which the term *Gryphæa*, or *Gryphites*, is applied, are related to the Oyster, but distinguished by the deep concave under valve, and its curved summit, or beak, and the almost flat, or

opercular upper shell. The Gryphites are of a finer laminated structure than the oysters, and the ligament of the

LIGN. 127. SHELLS AND ECHINITE FROM THE OOLITE AND LIAS.

Fig. 1.—TRIGONIA CLAVELLATA. *Oxford Clay, near Weymouth.*
2.—TRIGONIA GIBBOSA; a limestone cast. *Isle of Portland.*
3.—CIDARIS BLUMENBACHII. *Oolite. Calne, Wilts.*
4.—TRIGONIA COSTATA. *Oolite. Highworth, Wilts.*
5.—Spine of the Cidaris Blumenbachii.
6.—GRYPHÆA INCURVA. *Lias. Cheltenham.*
7.—AMMONITES WALCOTII. *Lias, near Bath.*

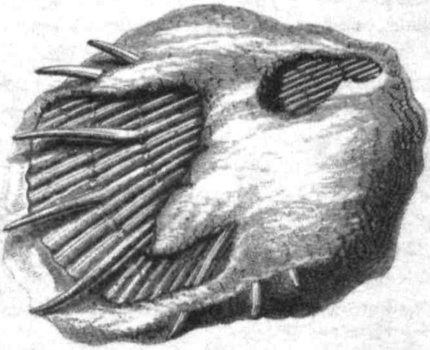
hinge is inserted in an elongated curved groove. There are about thirty British fossil species, none of which have been

noticed below the Lias, in which formation one very remarkable species is so abundant as to be considered characteristic of the Liassic deposits. It is so faithfully represented, *Lign.* 127, *fig.* 6, that description is unnecessary. In the upper argillaceous beds of the Oolite and Kimmeridge Clay, a very small gryphite, (*G. virgula*, *Ly.* p. 260) is so abundant, that it constitutes entire layers. The low cliffs on the west of Boulogne harbour, like those near Weymouth, are composed of this clay, and myriads of the gryphites are scattered on the shore, with other shells of the same deposits; these shelly beds are called *marnes à gryphées*, by the French geologists. A very large gryphite, *Gryphæa sinuata*, (*Min. Conch.* tab. 336,) is found in the Shanklin sand of the Isle of Wight, and of Kent and Sussex. At low water, in the sand along the shore under Dunnose Cliff, near Shanklin Chine, numerous specimens are always obtainable.*

SPONDYLUS. *Lign.* 128.—A species of this genus is so frequent in the Chalk, that it ranks with certain Terebratulæ, as characteristic of that formation. One valve is covered with long slender spines, which, in the usual examples, are destroyed by the mode of extracting them. The specimen figured shows the appearance of a shell partly cleared; the remainder of the chalk might be removed by a pen-knife (taking care to leave the longest spines supported by brackets of chalk), and it would then resemble the beautiful fossils figured *Min. Conch.* tab. 78, and in *Geol. S. E.* p. 125. Between the beaks there is a triangular aperture in the spinous valve, which some naturalists, with much probability, suppose was once filled up with shell, as in the recent species.

* The name *Exogyra* was applied to the Chama-shaped species of Gryphæa by the late Mr. Sowerby, and other writers; but subsequent authors have included these shells in the present genus.

In the cretaceous strata of North America, Dr. Morton has discovered a Spondylus (*S. dumosus*) very nearly related to *S. spinosus*; but it differs in its general form, and has both valves beset with strong spines. I have the fragment of a large bivalve from the Kentish Rag (Mr. Bensted's



LIGN. 128. SPONDYLUS SPINOSUS. *In Chalk-flint. Lewes.*

quarry), which has the peculiar structure of the Water-clam (*Spondylus varius* of Mr. Broderip); namely, hollow interspaces formed by shelly layers or partitions, which were secreted by the posterior part of the mantle, or investing integument of the animal, as it gradually receded from that part of the shell. In the recent Water-clam the cells are full of fluid.*

PLAGIOSTOMA, Llhwyd, 1699. This genus, adopted by Mr. Sowerby in the Mineral Conchology, is scarcely distinguishable from *Lima* of Bruguiere (1791). Most of the recent species are ornamented with small asperities, from which the name *lima* (file) is derived; they are symmetrical shells attached by a byssus.

* See Penny Cyclop. Art. *Spondylidæ*.

Several smooth species of this genus are found in the Chalk,* Oolite, and Lias. A very large species (*P. giganteum*), sometimes ten inches in diameter, abounds in the Lias (*Ly.* p. 274). It is somewhat depressed in form, with the surface slightly striated; each valve has a pointed beak, with two lateral expansions, or ears, as they are termed by conchologists.

PLICATULA, is another genus of this family, of which there are three British fossil species. A delicate shell, with slender depressed spines (*P. inflata. Foss. South D.* pl. xxvi.), occurs in the Chalk Marl. The recent species are natives of the seas of warm climates.

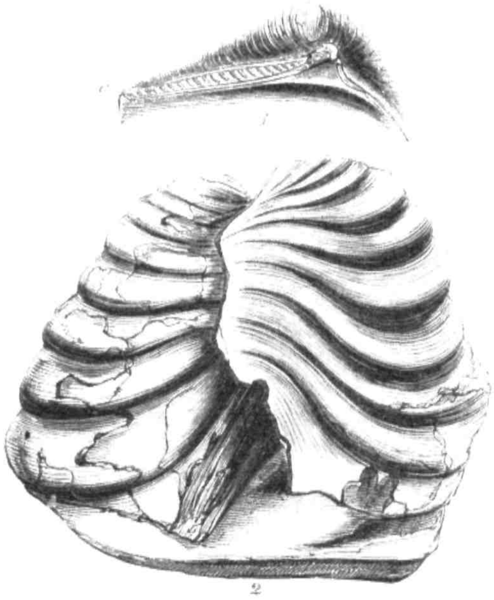
PECTEN.—The common scallop-shell will serve as a type of this genus. The animals of these shells, unlike the oysters, have the power of locomotion, and when in the water, may be seen moving with rapidity, and flapping their shells to and fro with great activity. Numerous species are found fossil. In the Pliocene, and other marine tertiary deposits, Pectens abound; in the White Chalk there are several elegant forms (see *Foss. South D.* plate xxv.); many kinds in the Oolite and Lias; and several in the Devonian strata.

A large Mediterranean species (*Pecten Jacobæus, Ly.* p. 152) occurs in the Pliocene strata of Palermo, in every stage of growth, and as perfect as if recent. The Chalk and Shanklin sand contain a small inequivalved Pecten, the lower valve of which is convex, and pentangular, the upper flat, and both strongly ribbed, or pectinated; it is named *Pecten quinquecostatus* (*Foss. South D.* pl. xxvi. *Ly.* p. 212); and in the cretaceous strata of North America a variety of this species is found.

In the Chalk Marl a large and beautiful Pecten (*P. Bea-*

* See Foss. South Downs, plate xxvi.

eri. *Min. Conch.* tab. 158) is very common, and I have obtained from Hamsey and Southerham examples in the most perfect state of preservation; it is a characteristic shell of the Chalk Marl of England (*Foss. South D.* plate xxv. fig. 11).



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Lign. 129. INOCERAMUS CUVIERI. *Chalk. Lewes.*

Fig. 1.—Beak and hinge of an INOCERAMUS.
a. The hinge line.
2.—Two valves of I. CUVIERI, displaced, and both showing the external surface.

INOCERAMUS. *Lign.* 129.—This name, which refers to the fibrous structure of the shell, has been given to a fossil genus, of which there are about thirty species in the cretaceous

and oolitic formations: and very recently four or five species have been discovered in the Silurian strata of Ireland.* These shells are chiefly characterized by their hinge (see *Lign.* 129. *fig.* 1*a*.), and by the fibrous structure of their constituent substance, which closely resembles that of the recent *Pinna*; † and under the microscope is found, like that shell, to consist of prismatic cells, filled with carbonate of lime.‡ The species vary in size from an inch to three or four feet in diameter. The shell, in consequence of the vertical arrangement of the fibres, readily breaks to pieces, and it is often extremely difficult to extricate a specimen with the hinge and beaks tolerably entire. That they were equally brittle when recent is evident from the numerous fragments diffused through the chalk and flint, and occasionally imbedded in pyrites.§ The form of the hinge is shown in *Lign.* 129. *fig.* 1: in the lower specimen two valves of the same individual are seen displaced, one lying over the other. The usual chalk species are figured *Foss. South D.* pl. xxvii. and in *Min. Conch.*

In the Galt, or Folkstone marl, two small species of this genus are to be found in every locality I have visited. They were first figured and described by Mr. Parkinson, under the name of *Inoceramus sulcatus*, and *I. concentricus* (*Wond.* p. 330, fig. 1 and 3). In most examples the shell is in

* The term Inoceramus is restricted by the French geologists to the beaked and laminated species of the Galt; and the chalk Inocerami are arranged under the name *Catillus*.

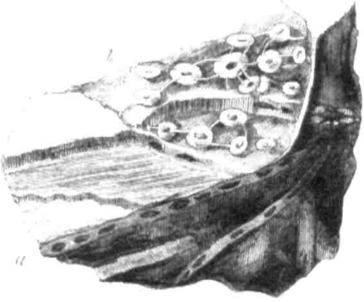
† *Perna* and all the Aviculidæ have the same structure. Inoceramus scarcely differs from Perna.

‡ Dr. Carpenter on the Microscopical Structure of Shells. To detect this structure, the shell should be immersed in diluted hydrochloric acid, and when partially dissolved, the cells will be apparent.

§ It was many years before I succeeded in obtaining a specimen with the hinge perfect; and M. Brongniart, unable to obtain one from the chalk of France, gave the figure of this genus from my Foss. South D. pl. xxvii. in the Géog. Min. Env. de Paris.

the state of a white, friable earth, and readily decomposes, leaving patches of iridescent nacre on the casts; but I have seen examples which prove that the originals were of a fibrous structure, like the Inocerami of the Chalk.

The shells of the Inocerami, like those of the oyster, and other living mollusca, were exposed to the attacks of some parasite, and perhaps of some Annelid, as the *Nereis*. The shells are often cellular from this cause, and the cavities are found either hollow, or filled with chalk, or, as in the example *Lign.* 130, with flint. In the latter case, upon



LIGN. 130. FLINT, WITH FRAGMENTS OF INOCERAMUS.

Chalk. Lewes.

a. Marks the section of a fragment of shell, with numerous cavities, occasioned by the depredations of Cliona Conybearei.

b. Portion of shell partially decomposed, and exposing siliceous, globular bodies, connected by filaments, which are flint casts of the hollows left by the Cliona.

the decomposition of the shell, the siliceous casts remain in relief on the surface of the flint, as in *Lign.* 130, *b*. Such specimens are common in the broken flints of the South Downs, and in the shingle on the sea-shore of chalk dis-

tricts; and their origin would be difficult to understand without this explanation.*

AVICULA. *Lyell*, p. 274.—Above fifty species of this genus of shells have been found in the British strata; their general character will be readily understood by reference to the pearl-oyster, (*Avicula margaritifera*,) which is so largely imported for the manufacture of mother-of-pearl ornaments. A remarkable species is found in the Lias, called, from the great disproportion in the size of the shells, *Avicula inæquivalvis*, (*Lyell*, p. 274.) The recent species are inhabitants of warm climates.

Our limits will not admit of further notice of the *Monomyaria*, and we proceed to the second division of the plated-gilled mollusca.

DIMYARIA: *Bivalve Shells, with two muscular imprints.*

The conchifera, or bivalve shells, of this group, found fossil, are more than double in number those of the preceding; nearly eight hundred species are known in the rocks of Great Britain, of which by far the greater number is marine. But we must restrict our notice of this division to a few genera, that more space may be devoted to that important class, the Cephalopodous Mollusca.

The *Cardium*, *Venus*, and Mussel shells, are familiar examples of the *Dimyaria*. The conglomerates, now forming in the British Channel, from accumulations of the recent species of Cockle (*C. edule*), have been previously noticed; see *Lign.* 124, p. 386. In the strata of England

* The Rev. W. Conybeare first ascertained the origin of these fossils, and figured and described them in an elegant Memoir, published in Geol. Trans. vol. ii. first series. Mr. Morris proposes the name of *Clionites* for the fossil bodies derived from the depredations of the Cliona on the Inocerami and other shells. See Annals Nat. Hist. 1851, and my Pictorial Atlas of Organic Remains.

there are upwards of thirty species: the *Crag* contains several, particularly a large and delicate shell, the *Cardium Parkinsoni* (*Min. Conch.* tab. 49). Others are peculiar to the London clay, as the *Cardium semigranulatum*, a beautiful shell, having the surface smooth, except on the posterior side, which is covered with strong ridges, beset with minute granules; it is found in many localities (*Min. Conch.* tab. 144). Among the silicified shells of the Shanklin sand of Devonshire, an elegant Cardium, *C. Hillanum*, (*Min. Conch.* tab. 14,) occurs. But one species is known in the formations below the Lias: the *Cardium striatum*, (*Murch. Sil. Syst.* tab. 6, fig. 2,) found in the Aymestry limestone.

Venericardia. *Ly.* p. 199.—These shells are abundant in the tertiary strata; one large species, *V. planicosta*, (*Ly.* p. 199, fig. 171,) is found in immense quantities in the clay and sand at Bracklesham Bay, in Sussex, from the young to the adult state; some examples are very large, and perfect. In the sand at Grignon, near Paris, the same shell is abundant, possessing the usual white and delicate aspect of the fossils of that celebrated locality of the *Calcaire grossier*. Only one species has been noticed in the British secondary strata.

Pectunculus. *Wond.* p. 244, fig. 8.—In the London clay at Bracklesham Bay, Highgate, Hordwell Cliff, and in the arenaceous limestone of Bognor rocks, an immense number of the bivalve shells, called *Pectunculi* (*little pectens*), occur. Some of the French marine tertiary strata also abound in the same, and other species of this genus. In the above-mentioned Sussex localities, these shells are so numerous, as to be the most frequent fossils that come under the notice of the collector. They are readily known from their associates by their rounded equivalve shells, and the single arched row of teeth along the hinge, resembling

the common *Arca*.* (See *Min. Conch.* tab. 27). At Plumstead, near Woolwich, a smaller species is found; and also occasionally with the oysters at Bromley.

NUCULA.—Several species of a small elegant bivalve, related to the preceding, but distinguished by having two rows of teeth on the hinge, diverging from an interspace between the beaks, are found in the Crag and other tertiary deposits (*Min. Conch.* tab. 180, 192). Two species occur in the Galt (*Foss. South D.* pl. xix. fig. 5, 6, 9), at Ringmer, Folkstone, Bletchingley, &c., sometimes with the shell perfect, but generally in the state of casts composed of indurated clay, and having impressions of the muscles and of the two rows of hinge-teeth. The shell of one species is marked with fine transverse grooves, or striæ (*N. pectinata*); the other is of a flattened ovate form, and the surface smooth (*N. ovata*).

The most beautiful species of *Nucula* are the *N. bivirgata* of the Galt of Folkestone, and *N. Cobboldiæ* of the Norwich Crag.

The species of *Nucula* with the posterior side produced into a long beak have been separated under the name *Leda*; they have a pallial sinus, indicating a siphon to the mantle;—

e. g.	*Nucula ovum* . . .	Alum Shale.
	— *claviformis* .	Lias.
	— *attenuata* . .	Coal Shale.
	— *arctica* . . .	Norwich Crag.

PINNA.—The common large *Pinna*, of the Mediterranean, is well known, and differs so entirely from other shells, as to

* The species so abundant at Bognor, is *P. brevirostris*, Min. Conch. tab. 472. I have seen a block of the limestone, in which, spread over an area of a foot square, there were upwards of fifty specimens lying in relief.

be readily distinguished. There are about fifteen or sixteen British fossil species. The earliest appearance of this genus is in the Carboniferous Limestone of Derbyshire (*Phil. York.* tab. 6), in which there are two species. The Lias contains one species; the Oolite eight; the Cretaceous formation four; and the London clay two. One of the tertiary species, *Pinna affinis* (*Min. Conch.* tab. 313), occurs in considerable numbers in the Bognor rocks, associated with Pectunculi; it varies in length from one to six or seven inches. A beautiful and delicate species is found in the *Calcaire grossier* of Grignon. Shells of this genus are very rare in the White Chalk, most of the supposed *Pinnæ* being imperfect examples of *Inocerami;* but I have seen specimens from Norfolk (collected by the late Mr. Woodward), and one from Sussex, in the cabinet of the Marquess of Northampton.*

Mytilus, or Mussel.—There have been found about twenty species of this well-known genus of marine shells in the British strata. They are sparingly distributed through the several formations, from the Silurian to the newer Tertiary. One species (*Mytilus Lyelli, Wond.* p. 405, fig. 2) occurs in the Wealden, associated with fresh-water shells.

Of the genus termed Modiola, which comprises those mussels that have a rounded anterior termination, nearly forty British species have been discovered; ranging through the fossiliferous strata, from the Silurian to the Crag. A beautiful species (*Modiola elegans. Min. Conch.* tab. 9), with the shell generally retaining its pearly coat, is found in the London Clay, and in the limestone of Bognor.

An undescribed striated *Modiola* (which may be named

* Dr. Lee has recently discovered in the Kimmeridge Clay on his estate at Hartwell, Bucks, a species of Pinna not previously observed in England. Professor Forbes informs me that it resembles *Pinna conica* (of Röemer), and is related to *P. lanceolata* of Sowerby, but appears to be distinct from both.

M. striata, since the striæ are peculiar), occurs in the Kimmeridge Clay, at Hartwell.

Those species of Modiola, which excavate hollows in stones, and inhabit them, are arranged in a genus termed *Lithodomus*. The occurrence of these shells in the remaining erect pillars of the Temple of Jupiter Serapis (*Wond.* p. 106), at Puzzuoli, has afforded important and unequivocal evidence of the physical mutations which that part of Italy has undergone. Two species of Lithodomi have been found, by Mr. Lonsdale, in the Oolite.

PHOLADOMYA. *Ly.* p. 272, fig. 290.—This genus of shells (established by Mr. James De C. Sowerby in the *Min. Conch.* 1826), comprises about twenty British fossils, all of which, with but two exceptions, occur in the Lias and Oolite. They are equivalved shells, with the posterior end short, and rounded, and the anterior elongated and gaping. The surface is generally marked with ribs, or alternate elevations and depressions, diverging obliquely from the beaks to the margin. In the clay at Osmington and Radipole, near Weymouth, a large species (*P. æqualis*, *Min. Conch.* tab. 546) is abundant. The Oolite of Brora, in Scotland, contains several species. The only species found in our Chalk, is the beautiful shell (*P. decussatum*), figured *Foss. South D.* tab. xxv. fig. 3, and first discovered by me, in 1820, in a bed of Chalk Marl, which at that time was exposed at low-water, at the base of the cliff at Brighton, near the present entrance to the Chain-pier. The same species has since been found at Clayton, Hamsey, Southbourn, and other localities of the Marl.

PHOLAS. *Lign.* 166, *fig.* 5, 6. — The common boring bivalve called *Pholas*, must have attracted the attention of every stroller by the sea-shore, from the numerous perforations in blocks of chalk, and other limestones, occasioned

by its operations. Some species burrow in wood, and often commit serious ravages in piles and other submarine works constructed of timber. In the earlier ages of our planet we find evidence of the existence of the same kind of living instruments for the disintegration of floating wood, and the reduction of masses of rock into detritus. But no traces of these shells have been found in strata below the Oolite. One species occurs in the Coral Rag, another in the Kimmeridge Clay; two in the Galt and Green Sand; and three or four in the tertiary deposits. In the Crag, blocks of stone are occasionally found with the shells of *Pholades* occupying the perforations they originally formed and inhabited. But all the specimens I have observed in the Galt, Green Sand, and Oolite were *xylophagous* (*wood-eating*) species. In the Shanklin Sand, masses of fossil wood, literally honey-combed by the perforations of Pholades, are frequent; but the shells themselves are rare. Mr. Sowerby has figured a beautiful specimen of silicified wood, from Sandgate, with numerous shells of this genus (*Pholas priscus. Min. Conch.* tab. 581). *Lign.* 166, *fig.* 5, represents a fragment of fossil wood, with three shells *in situ; a*, a shell seen longitudinally; and below, the rounded anterior extremities of two other shells are exposed.

Masses of wood perforated by Pholades, from which all traces of the shells have disappeared, have given rise to some curious fossil remains, which are often very enigmatical to the young collector. In the Kentish Rag, as for example, in Mr. Bensted's quarry, near Maidstone, large blocks of stone are found, covered with groups of subcylindrical mammillary projections, which are obtuse or rounded at the apex. In some examples the interstices between these bodies are free; in others they are occupied by a reddish brown, friable substance, presenting obscure indications of ligneous structure; and rarely, distinct woody fibres may be observed, the direction of which is transverse, or

nearly at right angles, to the mammillated projections. These blocks are, in truth, the stony casts of cavities formed by Pholades, in masses of wood, both the vegetable structure, and the shells, having perished.

In the White Chalk specimens of this kind are occasionally found.

A remarkable fact, relating to some of the specimens from the Iguanodon quarry, remains to be mentioned. Upon breaking off the projections, to ascertain if any traces of the shells of the Pholades remained, we discovered in several, near the apex, a univalve shell, a species of *Nerita*. *Lign.* 166, *fig.* 6, represents a fragment of stone with two of the casts, which have been broken, and in each, at *a*, a univalve is imbedded. At *b*, the ligneous structure of the original wood is visible. The only hypothesis that will account for the appearance of these univalves in their present position, is that of supposing that the Nerites crawled into the cavities made in the mass of timber, after the shells of the Pholades had been removed; and that the wood became imbedded in a sand-bank, and the univalves enclosed in the cavities; the ligneous structure in a great measure perished, and the stony casts of the perforations of the borers, with the imprisoned univalves, remained. The Nerites, as shown in the example figured, do not occupy any particular position in the tubes; one has the apex towards the end of the cavity, and the other lies in a transverse direction.*

TEREDO. *Ly.* p. 24.—It will be convenient to notice in this place another genus of boring shells, whose fossil remains are far more abundant than those of the Pholas. The *Teredo navalis*, or Ship-worm, which is the most ver-

* In a fragment of a perforated column, from Puzzuoli, in my possession, by favour of Sir Woodbine Parish, there were numerous living univalves in the cavities made and previously inhabited by the lithodomi.

miform of all the mollusca, forms tortuous cylindrical hollows in wood; and in some climates commits the most extensive injuries to ships, the piles of harbours, bridges, and other submarine works formed of timber. A reference to the illustration given by Sir C. Lyell will render detailed description unnecessary. The *Teredo* is furnished at one extremity with testaceous valves, by which it bores its way into the wood, while from the surface of its soft body a calcareous matter is secreted, which lines with a shelly covering the hollows or channels formed by the animal in its progress. The fossil species differ from the recent in the valves being united to the calcareous tube. Wood perforated by *Teredines*, and occupied by their shelly tubes, occurs in almost every locality of the London Clay. Those specimens in which the wood is petrified, and the cavities of the tubes are filled with calcareous spar of various colours, furnish beautiful sections, when cut and polished (*Pict. Atlas*, pl. viii. fig. 8, 9). When the canal in the Regent's Park was being formed, large blocks of perforated calcareous wood were discovered, having the ligneous structure well preserved, and the tubes of the Teredines occupied by yellow, grey, and brown spar, forming specimens of great beauty and interest. Wood, with Teredines, or some analogous boring mollusks, occurs sparingly in the chalk of this country; but in the cretaceous strata at Maestricht, large masses are frequently found.* Fossil wood may occasionally be observed with perforations that have been made by other kinds of boring shells; but the preceding remarks will suffice to convey an idea of the nature and origin of such appearances.†

* In the British Museum there is a mass of silicified wood from the Upper Green-sand of Blackdown, perforated by a Teredo, whose valves remain in the burrows.

† Other genera of boring shells also occur fossil, as Fistulana, Gastrochæna (Min. Conch. tab. 526), Saxicava (Min. Conch. tab. 466).

TRIGONIA. *Lign.* 127, *fig.* 1, 2, 4.—These bivalves are related to the *Arcadeæ* and *Nuculæ*, but distinguished by the peculiar character of the hinge; the right valve has two large oblong teeth, which diverge from the umbo, and are strongly furrowed, and fit into two corresponding grooved cavities, in the opposite, or left valve. These shells are very thick and nacreous; they abound in certain strata of the Oolite and lower Cretaceous formation, but have not been observed in any deposits of this country older than the Lias; there are nearly thirty British species. Two living species of Trigonia (*Trigonia margaritacea* and *T. Jukesii*) are known, both inhabitants of the seas of New Holland, where they are associated with Terebratulæ. Some of the argillaceous beds of the Oolite, as the Oxford and Kimmeridge clays, abound in Trigoniæ; Osmington and Radipole, near Weymouth, are celebrated localities for these fossil shells, which are found there in great perfection; and on the French coast, where similar strata appear, the Trigoniæ are equally abundant. Under the cliffs, near Boulogne harbour, the shore is strewn with them. Three common species are figured in *Lign.* 127. The casts of most of the species are smooth, as in *fig.* 2; and the collector should, therefore, search for impressions of the outer surface, when the shell is absent, as is generally the case in the Portland Oolite and Shanklin Sand, in which Trigoniæ are very numerous. Near Highworth, in Wiltshire, very fine and large examples of *Trigonia costata*, fig. 4, occur, with the shell preserved. The impressions of the large, oblong, diverging teeth of the hinge, are usually so strongly marked in the casts, as to render it easy to identify the shells of this genus. The quarries of the Portland Oolite at Swindon, Wilts, teem with casts of Trigoniæ, collocated with Ammonites. In the Isle of Portland they are also very numerous, some beds of stone being so friable, from the numerous cavities left by the removal of the substance of the shells, as to be unfit

for paving, or other economical purposes. Very sharp casts may be obtained from this rock by merely breaking the stone to pieces. In the Whetstone of Blackdown, Devon, beautiful silicified Trigoniæ are occasionally found. Tisbury, in Wiltshire, yields very fine specimens, and in some examples, Mr. G. B. Sowerby has detected remains of the ligament.

FOSSIL FRESH-WATER BIVALVES.

The animals of the shells hitherto described are, with scarcely any exception, inhabitants of the sea; and the marine origin of the strata in which they occur, may consequently be inferred, with but little probability of error. I now propose noticing the fossil remains of those bivalves which inhabit rivers, lakes, streams, and pools of fresh water. The marine, or fresh-water, character of fossil shells, is inferred from their resemblance to the recent mollusca, whose habits are known; for the shells alone present no unequivocal marks, by which even the experienced conchologist can pronounce whether an extinct form belonged to a marine or to a fluviatile mollusk, although certain characters may admit of an approximative inference. Thus, for instance, as none of the known living fresh-water bivalves belong to the previous division, the *Monomyaria*, the presence in a stratum of numerous shells with but one muscular impression, would afford a fair presumption of the marine origin of such deposit. The remains with which the shells are associated and the mineralogical characters of the strata in which they occur, would, of course, afford important corroborative evidence.*

The living fresh-water bivalves comprise but a few genera and species; and those which have been found fossil in the British strata belong to but four or five genera. Their dis-

* See Sir C. Lyell on the distinction between fresh-water and marine deposits. Ly. p. 27, *et seq.*

tribution is restricted to strata of undoubted fluviatile origin, and to those local intercalations of fresh-water and land productions in marine deposits, which occur in some of the secondary, and in many of the tertiary formations.

UNIO. *Ly.* p. 28.—The river Mussels, or *Unionidæ*, have a solid, pearly shell, with two principal and two lateral teeth on the hinge; and their umbones, or bosses, are generally smooth, or longitudinally undulated. Those which have no cardinal teeth are arranged under the genus *Anodon*: but it is not necessary for our present purpose, to enter into minute conchological distinctions. In number, variety, and beauty, the species which inhabit the large rivers of North America present a striking contrast with the few and homely British fresh-water mussels; nor have we, in a fossil state, any shells of this family at all comparable with those living types.* The earliest fossil Mollusca referred to the genus *Unio* appear in certain layers of clay and argillaceous ironstone belonging to the Carboniferous system of Derbyshire, Coalbrook Dale, &c. (*Min. Conch.* vol. i. tab. 33). In the former county, these strata are termed *mussel-band;*† and some beds constitute a compact shell-limestone, which admits of being manufactured into vases, &c., and takes a good polish; the sections of the shells in this marble are white, on a dark ground. There is, however, considerable doubt whether any of the Carboniferous shells really belong to the genus *Unio;* some geologists refer them to *Cardinia*, a group of sea-shells found especially in the Lias.

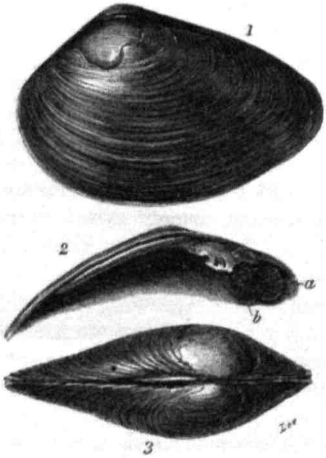
The earliest undoubted shells of this genus from the British strata, are, I believe, those first discovered by me in the strata of Tilgate Forest, (*Foss. South D.* p. 45, and *Foss.*

* See American Journal of Science, vol. xlvii. p. 402, "Unionidæ."

† "A solid stratum of ironstone, which extends from Tupton Moor to Staveley." Martin's Petrificata Derbiensia, pl. xxvii.

Tilg. For. p. 57), and subsequently found in numerous localities of the Wealden.*

In 1844 I discovered a large species in the Wealden at Brook Point. I have named it *Unio Valdensis.*† I have collected and obtained nearly fifty specimens; they present two varieties, the one contracted and narrow, the other broader and deeper; this difference is probably sexual; the wide and deep shells may be the females; for in the living American Uniones the same characters are observed. Some examples are remarkably well preserved; the ligament remaining in a carbonized state, and the body of the mollusk in the condition of molluskite; even a tint of the original tawny reddish colour of the shell is present.



LIGN. 131. UNIO VALDENSIS. (½ *nat.*)
Wealden; Isle of Wight.

The same species has been found in the Wealden strata, near Tunbridge Wells, by Mr. Barlow, C. E.

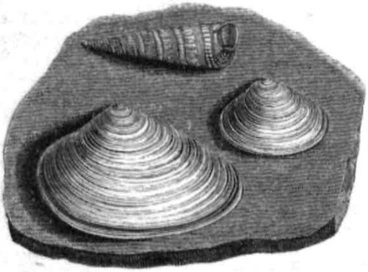
I shall reserve my remarks upon the important aid these

* They are figured in Geol. S. E. p. 250; and in Dr. Fitton's Memoir, Geol. Trans. vol. iv. pl. 21.

† *Unio Valdensis* resembles in form the Mexican species, U. Panacöensis (River Panaco), but is probably more nearly allied to an unnamed Australian species of which Mr. G. Sowerby has numerous examples.

fossils afforded in the determination of the fluviatile origin of the Wealden, for our *Excursion to Tilgate Forest.*

CYCLAS. *Wond.* p. 404. *Ly.* p. 28.—Another genus of fresh-water bivalves is termed *Cyclas*, of which there are ten species in the Wealden formation: and, with the exception of four or five recent forms, which occur in the tertiary fresh-water strata, none others have been found in England.*



LIGN. 132. CYCLAS AND MELANOPSIS. *Wealden; Sussex.*

The shells of the genus Cyclas are oval, transverse, equivalved bivalves, with the hinge-teeth very small: the substance of the shell is thin and fragile; the figures in *Wond.* and *Ly.* accurately represent the appearance of the fossil *Cyclades* of the Wealden, and tertiary strata. Entire layers of two or three species of these shells occur in the argillaceous deposits of the Wealden, generally in a friable state, but from among the masses of crushed shells, perfect specimens may be obtained, and sometimes with the remains of the epidermis and ligament. The hard stone, termed calciferous

* *Cyrena*, is a genus so nearly related to Cyclas, that it is difficult to distinguish them, and it will be convenient to retain only the former name.

grit, in the neighbourhood of Hastings, Tilgate Forest, Horsham, and other places in the Weald of Sussex, abounds in casts of the same species, associated with the *Uniones*, previously described. In the cliffs on the southern shores of the Isle of Wight where the Wealden beds emerge, and also in the Isle of Purbeck, these shells are equally abundant. Together with the *Uniones*, they occasionally appear in the limestone, called Sussex Marble; and in the Isle of Purbeck there are beds of limestone wholly composed ot bivalves belonging to these two genera, and presenting, in polished slabs, markings formed by sections of the enclosed shells.

FOSSIL PTEROPODA.

In the Ludlow strata there are found small fragile elongated conical shells without chambers, which are supposed by Professor E. Forbes to be identical with a recent genus of pteropodous mollusca, common in the Mediterranean, called Creseis. They seldom exceed two inches in length.

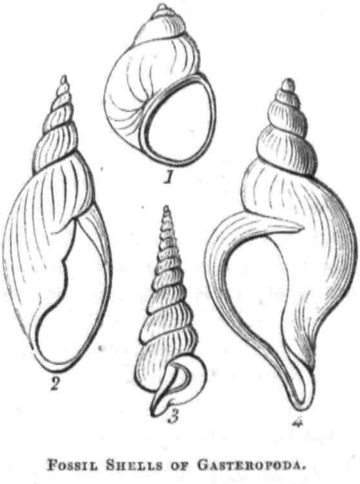
Of another genus, named Conularia, six species have been discovered in the Silurian formation.*

FOSSIL SHELLS OF GASTEROPODA.

The univalve shells, as we have previously explained, are the calcareous cases, or coverings, of a more highly organized class of molluscous animals, than the inhabitants of the bivalves (see p. 366), for they possess a head and mouth with jaws, eyes, and feelers; and while the *Acephala*, with but few exceptions, are incapable of locomotion, the *Encephala* are almost all of them furnished with organs of progression, and can creep, climb, and swim, or float on the surface of the water. Their shells are for the most part formed of one valve, hence the name of *univalve;* but in

* See Geol. Trans. second series, vol. vi. p. 325.

some species it is composed of several pieces. The most simple form of shell is that of the hollow cone, of which the *Patella*, or limpet, affords an example; and in the more complicated modifications, the cone is twisted, or convoluted spirally, either in the same plane as in the *Planorbis* of our rivers, or obliquely, as in by far the greater number of



LIGN. 133. FOSSIL SHELLS OF GASTEROPODA.

Fig. 1.—PALUDINA FLUVIORUM. *Wealden.*
2.—LIMNÆA LONGISCATA. *Tertiary. Isle of Wight.*
3.—CERITHIUM LAPIDORUM. *Tertiary. Grignon.*
4.—FUSUS CONTRARIUS. *Crag. Essex.*

species. The direction of the spire is generally from left to right, the aperture being dextral to the observer when the shell is placed with its apex uppermost, as in *Lign.* 133, *figs.* 1, 2, 3; but in a few species the spire turns in the opposite manner, and the mouth or aperture is to the left, or sinistral, as in *Lign.* 133, *fig.* 4. In consequence of the form of the aperture of the shell, the entire or notched

condition of its margin, and the presence or absence of a canal or siphon always having relation to the soft parts of the animal, these characters afford data by which the genera and species of the shells may be determined, and information obtained as to the structure and economy of the originals.

The Gasteropoda generally creep by means of a fleshy disk, or foot, which is situated under the belly. Some kinds are terrestrial, others inhabit trees, many live in rivers and streams, others in stagnant and brackish waters; but the greater number are denizens of the sea.

The Common Snail, River Snail, and Periwinkle, are instances of terrestrial, fluviatile, and marine forms. The organs of respiration are situated in the last whorl of the shell; and in some genera the border of the mantle, or integument surrounding the body, is prolonged into a siphon, by which the water is freely admitted, without the head or foot being protruded: in these mollusks the shell has a corresponding channel to receive the siphon, as in the Whelk, or Buccinum, and in the fossil shell *Lign.* 133, *fig.* 4. The Gasteropoda are generally provided with an operculum, or moveable valve, by which the aperture is closed and defended when the animal retreats within its shell. In some species the operculum is a mere horny pellicle; in others it is a solid calcareous plate of considerable relative thickness. These mollusca, as is but too well known of the terrestrial species, consume large quantities of food. Some are herbivorous, and others carnivorous; many prey on living, and others on decaying animal and vegetable substances.* As

* "All *Gasteropoda* commence life under the same form, both of shell and animal, namely, a very simple helicoid shell, and an animal furnished with two ciliated wings or lobes, by which it can swim freely through the fluid in which it is contained. At this stage of existence the animal corresponds to the permanent state of the *Pteropod*, and the form is alike, whether it be afterwards a shelled or

in a fossil state the shells alone remain to afford any clue as to the structure and economy of the originals, characters have been sought for, by which the fluviatile or marine nature, and the carnivorous or herbivorous habits of the living mollusca may be determined. As a general rule, it will be found, that the shells of terrestrial and fresh-water Gasteropoda have the aperture entire, as in the Garden Snail, and in the fossil shell, *Lign.* 133, *fig.* 1; and that a large proportion of the marine species have the opening notched or channelled, as in the Whelk, and *Lign.* 133, *figs.* 3, 4; and most of the species with entire apertures are herbivorous. But these inferences must be regarded in a very general sense, and it will require corroborative evidence to establish the marine or fresh-water nature of those fossil shells which do not bear a close analogy to known living species.*

The various conditions in which the remains of univalve shells occur in the mineral kingdom have already been so fully explained, that but a few additional remarks on that subject are required (see p. 382).

The *Gasteropoda* are found to progressively diminish in number with the antiquity of the deposits, and it was once supposed that this type of molluscous organization was not contemporaneous with the ancient Cephalopoda. My discovery of several genera associated with Ammonites in the chalk (see *Foss. South D.* pl. xviii, xix) first tended to invalidate this hypothesis; and the subsequent researches of Dr. Fitton, Professor Phillips, and other geologists have shown that the presence or absence of Gasteropoda in a stratum may generally be ascribed to the circumstance of

a shell-less species."—Prof. E. Forbes, Edin. Philos. Journal, vol. xxxvi. p. 326.

The well known Tiger Cowry (*Cypræa tigris*) in its earliest stage has a minute helicoid (snail-like) shell.

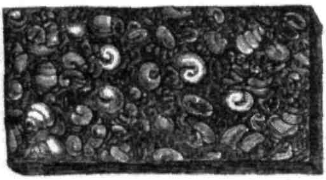
* See Ly. p. 30.

the deposit having been formed in shallow, or in deep water. Thus when simple univalves largely predominate under circumstances that indicate they were imbedded in their native habitats, it may be safely concluded that the rock is of littoral formation; or, in other words, was deposited in shallow water, near the sea-shore; and, on the contrary, when Nautili, Ammonites, and the shells of other mollusca known to live in deep waters abound in a formation, it may be presumed that the strata were formed in the tranquil depths of the ocean. The number of described species from the British strata is nearly eight hundred; and these are distributed throughout the sedimentary formations, from the Silurian to the newest Tertiary; the latter containing by far the greater proportion.

FRESH-WATER UNIVALVES.—The fossil shells of Gasteropoda that are undoubtedly fluviatile, comprise but few genera and species, and are confined to those deposits, which, from the corroborative proofs afforded by other organic remains, are unquestionably of fresh-water origin. Such are the intercalated beds of clay and limestone in the London and Paris basins, the Wealden formation, and certain strata in the Carboniferous system. The most numerous specimens are principally referable to the common fluviatile genera, *Paludina*, *Limnæa*, *Planorbis*, and *Melanopsis* (see *Ly.* p. 29).

PALUDINA. *Lign.* 133, *fig.* 1. (*Wond.* p. 401, *Ly.* p. 29.) —This common river shell is of a conoidal form, and the whorls of the spire, and the aperture, are rounded. Eleven British species are known. In the tertiary fresh-water beds of Headon Hill, at Alum Bay, Paludinæ with the shells perfect, and of a dull white colour, are abundant; and also in the limestone at Shalcombe, in the Isle of Wight, in the state of casts. In both these localities the Paludinæ are associated with other fresh-water shells. But the grand

deposit of shells of this genus is the Wealden formation; throughout which there are extensive beds of marble, coarse limestone, and clays, almost wholly composed of Paludinæ, and minute fresh-water Crustaceans, of the genus *Cypris*, which will be described in a subsequent chapter. The compact paludina-limestone of Sussex, called Petworth or Sussex marble, is principally made up of one species, the *P. fluviorum*, *Lign.* 133, *fig.* 1, and is an aggregation of Paludinæ, held together by crystallized carbonate of lime; the cavities of the shells, and their interstices, being often filled with white calcareous spar. A polished slab, displaying sections of the enclosed shells, is figured in *Wond.* p. 402. Upon examining slices of this marble with the microscope, the cavities of the shells are found to contain myriads of the cases of Cyprides.* The Wealden limestone of the Isle of Purbeck, *Lign.* 134, known as Purbeck marble, is, in like manner, composed of Paludinæ, but of a much smaller species. Both these marbles were in great repute with the architects of the middle ages, and there are but few of our cathedrals and ancient churches which do not still contain examples, either in their columns, monuments, or pavements, of one or both varieties. The polished marble columns of Chichester Cathedral, and those of the Temple Church, in London, are of Purbeck marble; in other words, they are composed of the petrified shells of snails, that lived and died in a river, flowing through a



LIGN. 134.

POLISHED SLAB OF PURBECK MARBLE.

* For a particular account of this marble, see Geol. S. E. pp. 182—187.

country inhabited by the Iguanodon and other colossal reptiles, all of which have long since become extinct. With the exception of the *mussel-band* limestone of the Carboniferous system, previously described, these are the only British fresh-water marbles.* There are four species of Paludina in the Wealden, and four in the Tertiary strata of Hants.

LIMNÆA. *Lign.* 133, *fig.* 2.—Several species of these fresh-water mollusks inhabit our lakes and ponds, and may be known by their pointed spire, elongated oval body, and delicate thin shell; on the inner lip of the aperture there is an oblique fold. Fossil shells of this genus are found with Paludinæ in the fresh-water tertiary deposits. Headon Hill and other localities in the Isle of Wight abound in these shells; and in the limestone of Calbourn beautiful casts are very numerous. The Paris basin yields several species; and there are six species in the Isle of Wight Tertiary; I have not observed any decided examples in the Wealden. In the sands and clays the shells are well preserved; in the limestones the casts only remain. Shells of another genus of fresh-water spiral univalves, termed *Bulimus* (*Ly.* p. 30), are found associated with the above. A large species (*B. ellipticus, Min. Conch.* tab. 337), occurs in the limestone at Binstead, near Ryde, and at Calbourn; I have collected specimens two inches long from the former locality; they are generally in the state of casts, with a white friable coating of the shell.†

PLANORBIS. *Ly.* p. 29. *Wond.* p. 400. — The shells of this genus are also numerous in our rivers and lakes, and

* The collector may obtain specimens, and polished slabs of these limestones, of Mr. Martin, mason, Lewes, Sussex.

† A very large species of *Limnæa* from Bavaria (labelled *L. maxima*) is in the British Museum. It is a cast six and a half inches long, and is placed with the recent shells. Prof. E. Forbes has discovered a Limneïd (*Physa*) in the Purbeck strata.

may be distinguished by their discoidal form, the shell being coiled up in a nearly vertical plane. There are about twenty living species; and sixteen are enumerated as fossil in the British tertiary; five occur in the Isle of Wight basin, in the localities of the fresh-water genera already mentioned; Headon Hill, in particular, yields shells of this genus in great abundance and perfection.

MELANOPSIS. *Ly.* p. 29.—These are spiral univalves, the appearance of which will be better understood by the figures, than by any description. I allude to this genus because a small species is very numerous, with the other fresh-water shells, at Headon Hill; and two or more species are found in the argillaceous strata of the Wealden (see *Geol. S. E.* p. 249, and *Lign.* 132).

MARINE UNIVALVES.—Of the fossil marine Gasteropoda there are no less than eighty genera in the strata of the British Islands, and the species amount to several hundreds. To distinguish the species and genera, reference must, of course, be made to works expressly devoted to fossil conchology, as Sowerby's *Mineral Conchology*, and *Genera of Fossil Shells;* or to the works of French authors, particularly those of Lamarck, edited by M. Deshayes, and of M. Blainville. The *Penny Cyclopædia* contains admirable notices of fossil shells, under the respective heads of the classes, orders, and genera, of the recent Mollusca.

BUCCINUM, of which the common Whelk is an example. —FUSUS, *Lign.* 133, *fig.* 4. *Wond.* p. 244.—PLEUROTOMA, *Ly.* p. 31. *Wond.* p. 244.—CERITHIUM, *Lign.* 133, *fig.* 3. *Wond.* p. 244.—ANCILLA, *Wond.* p. 244. *Ly.* p. 31. —VOLUTA, *Ly.* p. 202, fig. 180.—MUREX, *Ly.* p. 164.—ROSTELLARIA, *Ly.* p. 201.—To the eight genera here enumerated a very large number of the marine simple univalve shells belong; and they are principally found in Tertiary strata.

The animals of these shells are characterized by their respiratory organs, which are formed of one or two pectiniform gills, with a tube or siphon more or less elongated, for the free admission of sea-water to the branchial apparatus. This organization is indicated in the shell, either by a notch, or by a prolonged tubular canal. All the species are, with scarcely any exceptions, inhabitants of the sea, and carnivorous.

I have selected for illustration of the genus *Fusus*, a celebrated shell of the Crag, known among collectors as the "*Essex reversed Whelk*," *Lign.* 133, *fig.* 4; the spire is twisted in the opposite direction to the usual mode, and the mouth is consequently to the left of the observer; the same species occurs with the spire in the common direction. The shells of the genus *Pleurotoma* are distinguished by an incision, or notch, in the side of the right or outer lip; and those of *Cerithium*, by the form of the mouth, see *Lign.* 133, *fig.* 3. The latter is a very numerous genus, and more than two hundred fossil species are enumerated; it contains many elegant forms. The Tertiary strata at Grignon are particularly rich in these fossils; the shells are of a pearly whiteness, and as perfect as when recent. Some Cerithia are of considerable size; the *C. giganteum* is from ten to fourteen inches in length. The genus Potamides comprehends shells closely resembling the Cerithia in form, but which are inhabitants of fresh-water.* This is an instance of the difficulty which sometimes exists of arriving at certain conclusions as to the habits of the mollusks, from their testaceous coverings alone.

The Plastic Clay beds at Castle Hill, Newhaven, and in the vicinity of Woolwich, abound in two species of shells,

* Mr. Woodward informs me that they can only be distinguished when *fossil*, by the absence of *varices*, or "periodic mouths." The *recent* species are known to be inhabitants of fresh-water, by their dark epidermis, corroded points, and horny multi-spiral *opercula*.

which were originally described by Mr. Sowerby, as *Cerithia* (viz. *C. funatum* and *C. melanoides*),* but are now referred to the fresh-water genus, *Melania;* by some conchologists to *Potamides*. At Castle Hill they are accompanied by fresh-water bivalves, and leaves of dicotyledonous plants.

Of the genus *Rostellaria*, there is a remarkable species in the London Clay, called *R. macroptera*, from the large wing-like expansion of its outer lip, in adult specimens; see *Ly.* p. 201. An elegant Rostellaria is found in the Galt, at Folkestone,† (*Foss. South D.* tab. xix. figs. 12, 14,) and other localities; and also in the Chalk Marl.

Casts of a large ventricose, globular univalve, called DOLIUM,‡ have been found in the Chalk Marl, at Clayton, near Hurstpierpoint, in Sussex. This species is distinguished by its transverse tuberculated bands; it is a very rare production of the lower chalk of Sussex (*Min. Conch.* tab. 326). Turbinated shells related to *Trochus*, and belonging to several genera, occur in the Cretaceous deposits. As is the case generally with the univalves of this formation, but slight traces of the shells remain; the thin internal nacreous lining is sometimes found adhering to the cast.

In the Chalk of Touraine, species of the genera *Conus* (*Lign.* 135, *fig.* 1) and *Solarium* (*Lign.* 135, *fig.* 2) are found with the shells preserved. The specimens figured, *Lign.* 135, are selected to familiarize the student with the difference so commonly observable, between the outer surface of the casts, and that of the shells: in both these fossils the shells are marked externally with lines and

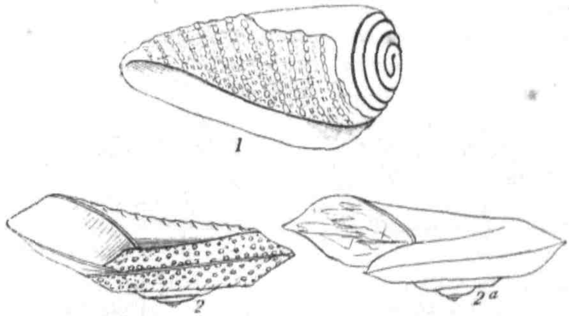
* Foss. South Downs, tab. xvii. figs. 3, 4.

† "This shell belongs to the recent genus, *Aporrhaïs*, and is related to Cerithium, not to Strombus."—*Mr. Woodward.*

‡ This Chalk fossil is not a *Dolium:* it is probably related to *Ringinella incrassata* (Geol. Suss. t. xix. fig. 3), one of the *Tornatellidæ*, a family largely developed in the chalk.

tubercles; but the casts present only the smooth surface of the interior of the shell in which they were moulded.

In the most ancient fossiliferous formations, the Carboniferous, Devonian, and Silurian, many species and genera of



LIGN. 135. UNIVALVES, FROM THE CHALK OF TOURAINE.—*nat.*

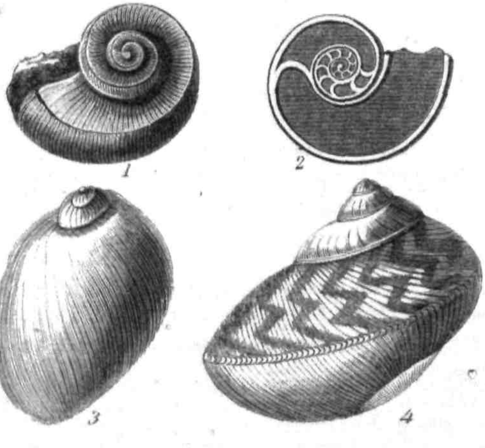
Fig. 1.—CONUS TUBERCULATUS, with part of the shell remaining attached to the cast.
2.—SOLARIUM ORNATUM, with the shell.
2*a*.—Specimen of the same species, deprived of the shell.

Gasteropoda have been discovered. Professor Phillips enumerates more than ninety in the mountain limestone of Yorkshire (*Phil. York.*), belonging to the genera *Turbo, Pleurotomaria, Natica, Euomphalus, Loxonema, Macrocheilus, Platyceras,* and *Metoptoma.* Thirty-four species from the Silurian rocks are figured and described in *Murch. Sil. Syst.* p. 706.

The *Natica, Lign.* 136, *fig.* 3, sometimes attains thrice the size represented, and has been found in many localities in England and Ireland.

PLEUROTOMARIA. *Lign.* 136, *fig.* 4.—This is an extinct genus, distinguished from *Trochus* by a fissure on the right lip, the position of which is indicated by the band along the

back of the whorl in *Lign.* 136; several species occur in the Mountain Limestone; the markings of the original shell are sometimes preserved, as in the example delineated. This genus is common in the Oolite; a splendid species, with the shell entire, is found in the Kimmeridge Clay, at Hartwell; limestone casts of the same species are abundant in the Portland stone at Swindon, in Wiltshire.



LIGN. 136. UNIVALVES FROM THE MOUNTAIN LIMESTONE.

Fig. 1.—EUOMPHALUS PENTANGULATUS; upper surface.
2.—Polished section of the same species.
3.—NATICA PLICISTRIA. *Yorkshire. Mt. L.*
4.—PLEUROTOMARIA FLAMMIGERA. (*Phil. York.*) *Mt. L.*

There are two species of this genus (formerly named *Cirrus* by Mr. Sowerby) which are of frequent occurrence in the White Chalk of England, in the state of casts, and are figured in my *Foss. South D.* tab. xviii., under the names of *Cirrus perspectivus*, and *Trochus linearis.* The Chalk Marl of Sussex yields in some localities (Hamsey,

Middleham, Clayton) fine casts of Pleurotomaria, which appear to be distinct from those of the upper cretaceous strata.

Euomphalus.* *Lign.* 136, *figs.* 1, 2.—The shells of this extinct genus are deeply umbilicated, discoidal, spiral univalves, having the innermost whorls of the shell divided by imperforated partitions. The internal structure of these shells will serve to prepare the student for those more complicated forms of the testaceous apparatus presented by the Cephalopoda, which will form the subject of the next chapter. There are several recent univalves the animals of which retreat in the progress of growth from the apex of the spire, and the vacated portion is shut off by a shelly plate. In some genera a series of concave septa are thus formed; but in others (as *Magilus*) the deserted cavity is filled by a compact accretion of calcareous matter, and a solid elongated shell is produced. The *Euomphalus*, of which there are many species in the Silurian, Devonian, and Carboniferous strata, belongs to the former group. As the animal increased in size, it deserted the smaller and innermost portion of the spire, and a nacreous partition was secreted by the posterior part of the mantle, the interspace remaining hollow; as this process was repeated at different periods, several cells were successively formed. This chambered structure is shown in the specimen *Lign.* 136, *fig.* 2, in which the cells are filled with spar, but the outer cavity is occupied by limestone like that in which the shell was imbedded; a proof that no communication existed between the chamber occupied by the body of the animal, and the space from which it had withdrawn. The calcareous spar, as in the vegetable remains previously described (p. 71), has percolated the substance of the fossil, and crystallized in

* So named by Mr. Sowerby, in allusion to the deeply umbilicated character of the disk.

the innermost cells. We shall again have occasion to refer to this interesting fact, when investigating the chambered cells of the Cephalopoda. It may be necessary to remark, that it does not appear that the vacant interspaces in the Euomphalus served the special purpose of the air-chambers of the Nautilus and Ammonite.

MURCHISONIA. *Lign.* 137. An elongated spiral shell, having the outer lip deeply notched, as in the Pleurotomaria (*a*, *Lign.* 137). There are upwards of 50 species of this genus, which are characteristic of the palæozoic rocks. They occur in the Permian, Devonian, and Lower Silurian deposits; the specimen figured is from the Devonian, or Old Red of the Eifel.

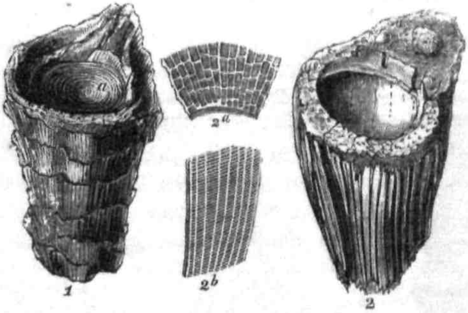
LIGN. 137.
MURCHISONIA ANGULATA.
Devonian; Eifel.

CHITON. Valves of Chitons have been found in the Magnesian limestone, near Sunderland, by Prof. King, (*Permian Fossils, Pal. Soc.* p. 202, pl. xvi.), and in the Silurian rocks of Ireland, by Mr. Salter, *Geol. Journal*, vol. iii. p. 48.

SPHÆRULITES.* *Lign.* 138.—No vestiges of a shell of this genus had been noticed in the English strata, until my discovery of some fragments in the Lewes Chalk in 1820; from the lamellated structure of these fossils, I mistook them for corals, until specimens were obtained sufficiently perfect to show the form of the originals; these were described in the *Geol. S. E.* (p. 130), under the name of Hippurites. But these fossils are more nearly related to the *Sphærulites*, which differ from the

* This genus has been referred by some conchologists to the Bivalves, and by others to the Univalves.

shells of the former genus in having only one internal longitudinal ridge, and in the external surface being roughened by irregularly raised plates, as in *Lign.* 138, *fig.* 1, which is a specimen from the Pyrenees, collected by M. Alex. Brongniart; the operculum is seen at *a*.



LIGN. 138. SPHÆRULITES FROM THE CHALK OF FRANCE AND ENGLAND.

Fig. 1.—SPHÆRULITE, with its *operculum*, *a*.
2.—SPHÆRULITES MORTONI (G. A. M.), *from Lewes*: ½ *nat.*
2a.—Cellular structure of fig. 2, in a transverse section: ×
2b.—Structure, as seen in a vertical section: ×

The species found in the Sussex Chalk, *Lign.* 138, *fig.* 2, is characterized by the longitudinal striæ on the outer surface. In some examples there is an external longitudinal furrow, and a corresponding internal ridge.*

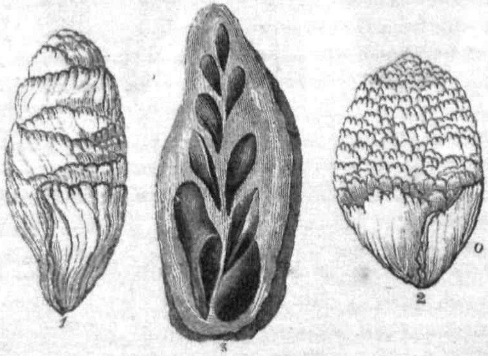
The Sphærulites sometimes occur in groups in the Sussex chalk; I had a large water-worn mass, consisting of five or six individuals, anchylosed together. Some beautiful specimens collected by the late Mr. Dixon from the Chalk, near Worthing, are now in the British Museum.† The structure of the Sphærulite is accurately delineated in *Lign.* 138,

* The specific name is in honour of Dr. George Morton, of Philadelphia, author of the "Synopsis of the Cretaceous Group of the United States."

† Petrifactions, p. 468.

figs. 2ᵃ, 2ᵇ. The cavities of these shells are occasionally filled with flint, but in general with chalk, which may be entirely cleared away, as in *fig.* 2. The Hippurites of the limestone of the Pyrenees are frequently occupied by calcareous spar, and the substance of the shells is occasionally transmuted into the same mineral.

MOLLUSKITE; OR THE CARBONIZED REMAINS OF THE SOFT PARTS OF MOLLUSCA.—Before proceeding to the consideration of that numerous and important division of the mollusca



LIGN. 139. COPROLITES AND MOLLUSKITE. *Chalk and Greensand.*

Fig. 1.—COPROLITE of a fish (*Macropoma*). *Chalk, Lewes.*
2.—COPROLITE of a fish (*Squalus*). *Chalk marl, Hamsey.*
3.—MOLLUSKITE of a *Rostellaria*. (*Mr. Bensted.*) *Kentish Rag, Maidstone.*

the *Cephalopoda*, I will offer a few remarks on a carbonaceous substance resulting from the gelatinous matter of which the soft bodies of these animals are composed, and for which I have proposed the name of *molluskite*, to indicate its nature and origin.

This substance is of a dark brown or black colour, and occurs either in shapeless masses, which are irregularly distributed among the shells and other organic remains, in sandstone, limestone, &c., or as casts of shells, or occupying their cavities, as in the specimen *Lign.* 139, *fig.* 3, which is a vertical section of a spiral univalve (*Rostellaria*), filled with the soft parts of the animal, converted into molluskite. Upon analysis this substance is found to contain a large proportion of animal carbon.* The rocks of firestone at Southbourne, on the Sussex coast, are mottled with brown molluskite and hard amorphous concretions, consisting of carbon and phosphate of lime, mixed with sand and other extraneous matter. Casts of shells, of the genera *Venus*, *Arca*, &c., entirely composed of the same kind of materials, are also abundant in those rocks. The lowermost bed of Galt, at its line of junction with the Green Sand beneath, at Folkstone, and in many other localities, is largely composed of similar matter, resembling in appearance the fossils called *Coprolites*, hereafter described. The outer chamber of the Ammonites and other shells, so abundant in the Galt, are often filled with this substance. But the most interesting deposit of molluskite is in the Kentish Rag of Mr. Bensted's quarry, near Maidstone. This phenomenon had not escaped the notice of that intelligent and accurate observer, who liberally placed at my disposal numerous shells, particularly

* Some of this *molluskite* has, at my request, been analyzed by Mr. Rigg, who obliged me with the following remarks:—"After removing the lime by means of hydrochloric acid from ten grains of this substance, there remained 1.2 grain of dark powder, which gave, by analysis with oxide of copper, .16 of a cubic inch of carbonic acid, and a small portion of nitrogen. On subjecting to the same kind of analysis two grains of the darker body, without previously acting upon it by any acid, .054 of a cubic inch of carbonic acid was obtained; so that from these results there is no doubt but the darker portion of the *molluskite* contains about .35 per cent. of its weight of carbon in an organized state."

of *Trigoniæ* and *Terebratulæ*, which were filled with molluskite, and large slabs of the sandstone, full of concretionary and amorphous masses of the same. The latter, Mr. Bensted suggested, may have been derived from the soft bodies of the dead Mollusks, which, having become disengaged from their shells and aggregated together, had floated in the sea, until they became enveloped in the sand and mud, which have gradually consolidated into the arenaceous stone termed Kentish Rag. In illustration of this opinion, Mr. Bensted directed my attention to the following remarkable fact, related in the *American Journal of Science* :—In the year 1836, a fatal epidemic prevailed among the shell-fish of the Muskingum River, in the state of Ohio. It commenced in April, and continued until June, destroying millions of the mollusca that inhabited the beds of the tributary streams, and the river. As the animals died, the valves of the shells opened, and, decomposition commencing, the muscular adhesions gave way, and the fleshy portions rose to the surface of the water, leaving the shells in the bed of the river. As masses of the dead bodies floated down the current, the headlands of islands, piles of drifted wood, and the shores of the river, in many places, were covered with them ; and the air in the vicinity was tainted with the putrid effluvium exhaling from these accumulations of decomposing animal matter. The cause of the epidemic was unknown.

"Now nearly the whole of the shells in the beds of Kentish Rag," Mr. Bensted remarks, "have their shells open, as if they were dead before their envelopment in the deposit. And, from the large quantity of water-worn fragments of wood perforated by Pholades imbedded with them, it seems probable that this stratum had originally been a sand-bank covered with drifted wood and shells, thus presenting a very analogous condition to the phenomenon above described." The gelatinous bodies of the *Trigoniæ*, *Ostreæ*, *Rostellariæ*, *Terebratulæ*, &c., detached from their shells, may have been

intermingled with the drifted wood in a sand-bank; while, in some instances, the animal matter would remain in the shells, be converted into molluskite, and retain the form of the original, as in the spiral univalve, represented in section, *Lign.* 139, *fig.* 3.

A microscopical examination of the Maidstone molluskite detects, with a low power, innumerable portions of the nacreous laminæ of shells, intermingled with the carbonaceous matter, many siliceous spicula of Sponges, minute spines of Echinoderms, and fragments of Corals; these extraneous bodies probably became entangled among the floating animal matter. A large proportion of the shelly laminæ, examined with a high power, displays the peculiar structure of the *Terebratulæ* (see *Lign.* 126, *fig.* 2^{a}), of which several species are abundant in the Kentish Rag.

The dark masses and veins so common in the Sussex and Purbeck marbles are produced by molluskite. If at the period of their envelopment the shells were empty, they became filled either with grey marl and limestone, or with white calcareous spar; but if they enclosed the bodies of the Mollusks, the soft mass was changed into carbonaceous matter; and in polished sections of the marble, the *molluskite* appears either in black or dark brown spots, or fills up the cavities of the shells. The dark blotches and veins observable in the fine pillars of Purbeck marble in the Temple Church, London, are produced by *molluskite;* and the most beautiful slabs of Sussex marble owe their appearance to the contrast produced by this black substance in contact with white calcareous spar.*

Carbon, resulting from animal remains, is of frequent occurrence in many strata; and the fetid emanations from

* See a "Memoir on the Carbonized Remains of Mollusca," by the author. Read before the Geological Society of London, February, 1843; and published in the American Journal of Science.

certain limestones, upon being broken or rubbed, are attributable to the evolution of sulphuretted hydrogen, from the animal matter which they contain.

GEOLOGICAL DISTRIBUTION OF THE BIVALVE AND UNIVALVE MOLLUSCA.—If the more rare and splendid organic remains may be regarded as the "*Medals of Creation*," the fossil testaceous mollusca, from their durability, numbers and variety, may be considered as the *current coin* of Geology. Occurring in the most ancient fossiliferous strata in small numbers, and of peculiar types,—becoming more abundant and varied in the secondary formations,—and increasing prodigiously, both numerically and specifically, in the tertiary, these relics are of inestimable value in the identification of a stratum in distant regions, and in the determination of the relative age of a series of deposits. To the solution of the former problem the sagacity of the late Dr. William Smith first suggested their applicability;* while the idea, so happily conceived, and so philosophically carried out, by Sir C. Lyell, of arranging that heretofore chaotic mass of deposits, termed the Tertiary, into groups, by the relative number of recent and extinct species of shells, demonstrated the important aid to be derived from this class of organic remains, in the determination of some of the most difficult questions in geological science.

Many useful tables have been constructed by Professor Phillips,† Sir C. Lyell, M. Deshayes, M. D'Orbigny, Prof. E. Forbes, and other eminent observers, to illustrate the geological distribution, in the several formations, of the genera and species of fossil shells hitherto described. To

* See an interesting memoir of Dr. Smith, from the pen of his distinguished nephew, Professor Phillips.

† A Treatise on Geology; and Art. *Geology*, Encyclopæd. Metropolitana.

the English student, Mr. Morris's "Catalogue of British Fossils," of which an enlarged edition is in the press, will be the most valuable for reference. In the works which we have especially recommended for reference (*ante*, p. 10), figures are given of some of the characteristic shells from each formation, as follow; commencing with the most ancient deposits.

SILURIAN SYSTEM. *Ly.* p. 350.

Orthis orbicularis; *Ly.* fig. 409.
—— grandis;—fig. 427.
Terebratula navicula;—fig. 410.
———— Wilsoni;—fig. 413.
Pentamerus Knightii;—fig. 411.
———— lævis;—fig. 426.
Atrypa reticularis;—fig. 414. *Wond.* p. 786.
Lingula Lewisii; *Ly.* fig. 412.
Strophomena depressa;—fig. 421.

DEVONIAN SYSTEM. *Ly.* p. 342.

Calceola sandalina; *Ly.* fig. 403.
Stringocephalus Burtini;—fig. 404.
Megalodon cucullatus;—fig. 405.

"The SILURIAN SYSTEM," by Sir R. I. Murchison, a splendid work on the rocks and fossils of the above formations, contains numerous figures of the shells peculiar to each group of strata; and many other species are delineated in the Memoir on the Devonian deposits of Devonshire and Cornwall, by Sedgwick and Murchison, *Geol. Trans. New Series*, vol. v. plates lii.—lvii. A Memoir on the Palæozoic Rocks of Germany and Belgium, by the same distinguished geologists, is also accompanied by many figures of fossil shells belonging to the same geological epochs. *Geol. Trans. New Series*, vol. vi.

See also Prof. M'Coy's "Silurian Fossils of Ireland," and his Description of the British Palæozoic Fossils in the Woodwardian Museum at Cambridge, in Prof. Sedgwick's "SYNOPSIS OF THE CLASSIFICATION OF THE BRITISH PALÆOZOIC ROCKS," of which two Parts are already published.

CARBONIFEROUS SYSTEM. *Ly.* 308. *Wond.* p. 736.

Producta punctata; *Wond.* p. 736.
——— Martini; *Ly.* fig. 390.
Pleurotomaria flammigera; *Lign.* 136, fig. 4.
Euomphalus pentangulatus; *Lign.* 136, fig. 1.
Natica plicistria; *Lign.* 136, fig. 3.
Spirifera trigonalis; *Wond.* p. 736.
——— triangularis; *Wond.* p. 736.
——— glabra; *Ly.* p. 389.
Serpula carbonaria; *Ly.* fig. 375.
Avicula papyracea;—fig. 378.

For the shells of the Mountain Limestone, reference should be made to the second vol. of Prof. Phillips's "Geology of Yorkshire;" to Prof. M'Coy's "Carboniferous Limestone Fossils of Ireland;" and to Prof. de Konick's "Anim. Foss. Belg." The fossils of other portions of the Carboniferous System are illustrated in Phillips's "Palæozoic Fossils of Devon;"* and in Prestwich's Memoir on Coalbrook Dale (*Geol. Trans.*).

MAGNESIAN LIMESTONE AND TRIAS. *Ly.* p. 301.

Producta calva; *Ly.* p. 203, fig. 337. } Permian.
Spirifera undulata;—fig. 338. }
Posidonia minuta;—p. 288, fig. 321. } Triassic.
Avicula socialis;—fig. 322. }

Prof. King's elaborate Monograph on the Permian Fossils (published by the Palæontographical Society) should be consulted by the student.

LIAS. *Ly.* p. 273.

Pleurotomaria Anglica; *Ly.* p. 39.
Avicula inæquivalvis; *Ly.* fig. 302.
Plagiostoma giganteum; *Ly.* fig. 303.
Gryphæa incurva; *Lign.* 127.

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* To prevent confusion, it may be necessary to state that Professor Phillips, in the work referred to, terms the Silurian strata the "*lower palæozoic*," and the mountain limestone, the "*upper palæozoic*."

OOLITE. *Ly.* p. 257.

Gryphæa virgula; *Ly.* fig. 268.
Ostrea deltoidea (Kimmeridge Clay);—fig. 269.
Trigonia gibbosa;—fig. 270.
——— clavellata; *Lign.* 127.
——— costata; *Lign.* 127.
Nerinæa Goodhallii; *Ly.* fig. 274.
Diceras arietinum;—fig. 275.
Pleurotomaria;—fig. 299.
Terebratula spinosa;—fig. 297.
——— digona;—fig. 283.
Ostrea Marshii;—fig. 300.
Phasianella Heddingtonensis;—fig. 58.

Many of the characteristic shells of the Oolite and Kimmeridge Clay, are figured in Plates XXII. and XXIII. of Dr. Fitton's Memoir on the Strata below the Chalk; *Geol. Trans. New Series*, vol. iv.

The fossil shells of the Great Oolite are figured and described by Messrs. Morris and Lycett, in the Memoirs of the Palæontographical Society; and valuable Papers on the Brachiopods of the Oolite and Lias, by Mr. Davidson, have been published by the same Society.

WEALDEN AND PURBECK. *Wond.* vol. i. *Geol. S. E.*, *Foss. Tilg. For.*, and *Ly.* p. 225.

Melanopsis; *Wond.* pp. 401 and 404.
Cyclas;—p. 404.
Paludina Sussexiensis;—p. 401.
Neritina Fittoni;—p. 401.
Mytilus Lyellii;—p. 405.
Unio antiquus; *Geol. S. E.* p. 250, fig. 1.
—— compressus;—fig. 2.
—— aduncus;—fig. 3.
—— porrectus;—fig. 4.
—— Valdensis;—*Min. Conch.* pl. 646, and *Lign.* 131.
Corbula alata; *Ly.* p. 229.
Ostrea distorta;—p. 232.

The shells of the Wealden are also figured by Dr. Fitton, *Geol. Trans. New Series*, vol. iv. Pl. XXI.

CHALK FORMATION.

I.—SHANKLIN, OR LOWER GREENSAND. *Ly.* p. 219.

Dr. Fitton's Memoir, previously quoted, contains numerous figures of the characteristic shells of this division of the Chalk, particularly of the species which abound in the celebrated *Whetstone* of Devonshire. *Geol. Trans. New Series,* vol. iv. Pl. XIII—XVIII. See also Prof. E. Forbes's Catalogue of Lower Greensand Fossils, in the Quart. Geol. Journal, vol. i.

II.—GALT AND UPPER GREENSAND. *Wond.* p. 307; *Ly.* p. 218.

Inoceramus concentricus; *Wond.* p. 330, fig. 1.
——— sulcatus;—fig. 3.
Terebratula lyra; *Ly.* fig. 219.
Pecten quinque-costatus;—fig. 203.
Ostrea carinata;—fig. 204.

In Plates XI. and XII. of Dr. Fitton's Memoir, there are figures of more than twenty characteristic shells of this division of the Chalk.

III.—WHITE CHALK. *Ly.* p. 211, *Foss. South D., Geol. S. E.*

Some cretaceous species are delineated in *Lign.* 125, 126, 128, 129, 130, 138; and Sir C. Lyell figures other species; but I must refer the student to the *Foss. South D., Geol. S. E.,* and Dixon's *Fossils of Sussex,* as accessible works containing numerous figures of the fossil shells of the Chalk. Accurate descriptions and representations of all the British chalk shells, however, are still much required. Mr. Davidson has done much towards the illustration of our Cretaceous Brachiopods; and the shells of the Cretaceous strata of the United States are figured and described in an elegant work by Dr. Morton, of Philadelphia.

TERTIARY FORMATIONS.

I.—EOCENE. *Ly.* p. 174; *Wond.* p. 226.
II.—MIOCENE. *Ly.* p. 168.
III.—PLIOCENE. *Ly.* p. 161.

The specimens figured by Sir C. Lyell have been so carefully selected, and are so well engraven, as to present a *coup-d'œil* of the most characteristic shells of the three grand divisions of the Tertiary Deposits.

I have reserved for especial mention in this place, the work, which will afford the student of British fossil Conchology the most important aid in the identification of specimens, namely, the "*Mineral Conchology of Great Britain,*" by the late eminent naturalist, Mr. JAMES SOWERBY, and continued by his son, Mr. James De Carle Sowerby; in six volumes 8vo., with several hundred coloured plates. Unfortunately, this work has long been discontinued; and the rapid progress of discovery, and the numerous foreign publications on every department of fossil conchology, almost forbid the hope that it will be resumed by the present proprietor. Although the high price of this work places it beyond the reach of many individuals, it will be found in most libraries of Natural History.

ON THE COLLECTION AND ARRANGEMENT OF FOSSIL SHELLS.—The instructions already given for the collection of corals, echinoderms, &c., will have familiarized the student with the methods generally adopted, and render it unnecessary to enter into much detail. The shells in arenaceous deposits, particularly in those of the Tertiary formations, are commonly so perfect, as merely to require careful removal: those in the clays are more fragile, and must be extracted with great caution; and, when very delicate, should be left attached to the clay or shale. The specimens extracted entire may be kept either in paper trays, lined with wadding, or fixed to pieces of card or thin board covered with paper, by thick gum-water; three or four specimens being attached in different positions, so as to expose the essential characters, as the aperture, spire, and back of the univalves, and the hinge, muscular imprints, &c. of the bivalves. Where only casts remain, search should be made for an impression of the outer surface of the shell, and a cast taken of it in wax, kneaded bread, or plaster of Paris. In indurated clays, sometimes both shells and casts may be obtained; and a specimen

of each should be preserved. Mastic varnish, or solution of gum tragacanth, delicately applied to fragile shells, tends to preserve them, and improves their appearance. It is desirable to collect the same species in various states of growth; the form of the young shell (as in *Rostellaria ampla*, of Solander) often differing essentially from that of the adult. It will be found convenient to have trays or boards of different colours; and to select one tint for the shells collected from a particular formation, or deposit; for example, the newer Tertiary may be placed on yellow paper; the older, or Eocene fossils, on light-blue. It is also desirable to separate the marine from the fresh-water species.

Shells imbedded in chalk, limestone, &c., often require much labour to display their more delicate and important characters. For clearing chalk specimens, a stout penknife, and a few gravers or gouges of various sizes, will be necessary; and by a little practice, the spines of the Spondylus (*Lign.* 128), and the beaks and hinge of Inocerami (*Lign.* 129), &c., may be readily exposed. A small stiffish brush, used with water, is also serviceable. The shells in compact stone, as those of the mountain limestone, must generally be cleared with the hammer and chisel. Common species may be broken out, and, from several examples, probably one or two will be found perfect; but choice and rare specimens should not be thus risked; they will amply repay the trouble of the less expeditious method of chiselling away the surrounding stone. Casts may be taken in gutta percha, &c.

To determine the names of the specimens that he has collected should be the next care of the student. No method will so readily initiate the young collector in fossil conchology, as the careful examination of a small series of the common species, with their names attached.* By the

* Such a series may be obtained, at very little cost, of dealers in objects of natural history; as, Messrs. Tennant, Sowerby, the British Natural History Society, &c. See Appendix.

geological map,* the nature of the deposit in which the locality of the specimens is situated, may be ascertained; and the remarks previously advanced on the prevailing shells of each formation, will afford a general idea of the genera to which they belong; and, by referring to the figures quoted, the specific names may be determined.

I subjoin a list of some localities of fossil shells, to direct research in places which are likely to be productive.

BRITISH LOCALITIES OF FOSSIL SHELLS.

Aldborough, Suffolk. The usual shells of the *Crag.*

Alum Bay, Isle of Wight. Eocene tertiary; marine and fresh-water shells.

Ancliff. Great variety of minute shells of the Oolite.

Arundel, Sussex. Chalk-pits in the neighbourhood.

Atherfield, Isle of Wight. Shells of the lower beds of the Lower Greensand, in great variety and abundance.

Aylesbury, Bucks. Kimmeridge Clay: near Hartwell.

Aymestry. *Pentamerus,* and other Silurian shells.

Barnstaple, North Devon. Numerous Devonian shells.

Barton Cliff, Hants. Eocene shells in profusion.

Bedford. Lower Oolite, *Terebratulæ, Ostreæ, Myadæ,* &c.

Binstead, near Ryde, Isle of Wight. Tertiary: in the stone-quarries, terrestrial and fresh-water shells, as *Bulimus, Helix, Limnæa,* and *Planorbis.*

Blackdown, near Collumpton, Devon. Greensand. Numerous silicified shells, of great beauty. *Trigonia, Venus, Corbula, Rostellaria,* &c. &c.

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* A Geological Map of England and Wales, coloured by Mr. Woodward, under the direction of Sir R. I. Murchison, has been published by the Society for the Diffusion of Useful Knowledge, at the low price of 5*s.* Although on a very small scale, and therefore not to be compared for utility and convenience with that by Prof. Phillips, much less with Greenough's large map, or with Knipe's, it will be found serviceable.

Bognor Rocks, Sussex. Eocene Tertiary. *Vermetus, Pectunculus, Pinna, Voluta,* &c.
Bolland. Numerous shells of the Mountain Limestone.
Bradford, Wilts. Numerous Oolitic shells. *Avicula.*
Bramerton Hill, near Norwich. Shells of the Norfolk Crag.
Brighton. *Strondylus, Terebratula, Ostrea, Pecten, Inoceramus,* &c. Many species in the chalk.
Bromley, Kent. Eocene Tertiary. Oyster conglomerate.
Brook-point, Isle of Wight: about one mile east of the Chine. Wealden: *Unio valdensis, Cyclades, Paludinæ,* &c.
Brora, Scotland. Oolite. *Pholadomya, Sanguinolaria,* &c.
Calbourn, Isle of Wight. Tertiary. Fresh-water Univalves.
Cambridge. In the Galt and Chalk-marl, the usual shells.
Castle Hill, near Newhaven, Sussex. In the Tertiary strata, on the summit of the hill. Numerous *Potamides, Cyclades,* and other fresh-water shells. *Ostreæ,* with pebbles.
Chardstock, Devon. The fossils of the Lower Chalk.
Cheltenham. Fine shells of the Oolite and Lias.
Chute, near Longleat, Wilts. Greensand shells, in abundance.
Clayton, near Hurst, Sussex. In Chalk-marl, many rare shells; as, *Dolium nodosum* (*Min. Conch.* tab. 326.)
Clifton. Carboniferous Limestone. *Spirifera, Producta,* &c.
Coalbrook Dale. Silurian and Carboniferous fossils.
Cork. In the vicinity. Carboniferous limestone shells.
Crich Hill, Derbyshire. The usual shells of the Mountain Limestone.
Cuckfield, Sussex. In the Sandstone and Grit, fresh-water shells of the Wealden.
Dudley. Profusion of shells of the Silurian strata.
Dundry, near Bristol. Beautiful shells in the Inferior Oolite.
Earlstoke, Wilts. Many shells of the Greensand.
Faringdon, Berks. The usual shells of the Oolite in the Coral Rag, &c.; and of the Greensand, in the Gravel-pits.
Folkstone, Kent. Galt. *Inoceramus, Arca, Rostellaria, Dentalium,* &c. Lower Greensand, *Gryphæa, Ostrea,* &c.
Gravesend. Beautiful shells of the White Chalk.
Hampstead Cliff, Isle of Wight. Fresh-water Tertiary shells.
Hampton Quarry, near Bath. Abounds in Oolitic shells.
Hartwell, Bucks. On the estate of Dr. Lee, beautiful shells of the Kimmeridge Clay.
Harwich Cliff, Essex. The Crag shells. *Voluta Lamberti.*
Hastings, Sussex. Fresh-water shells of the Wealden.
Headon Hill, Isle of Wight. Fresh-water Tertiary shells in profusion.
Heddington. Oysters in Kimmeridge Clay (*Ostrea deltoidea*). *Perna, Gervillia, Trigonia,* &c.

Highworth, Wilts. Very fine Trigoniæ, and other Oolitic shells, in the stone-quarries.

Hollington, near Hastings. Wealden. Fresh-water bivalves, &c.

Holywell, near Ipswich. Shells of the Crag, abundantly.

Hordwell Cliff, Hants. The usual shells of the Eocene deposits, in immense quantity, variety, and perfection.

Horningsham, near Frome, Wilts. Oxford Clay. *Terebratula*, *Pecten*, &c. in great numbers.

Horsham, Sussex. Fresh-water shells of the Wealden, in the stone-quarries.

Humbleton Hill, Sunderland. Permian fossils.

Hythe, Kent. Greensand. *Trigonia*, *Gryphæa*, *Pecten*, &c.

Ilminster, Somerset. *Brachiopoda*, &c. Inf. Oolite and Merlstone.

Ipswich. The usual Crag shells.

Langton Green, near Tunbridge Wells. Wealden. In the sandstone quarries, *Uniones*, *Cyclades*, &c.

Leckhampton Hill, near Cheltenham. Numerous shells of the Inferior Oolite and Lias.

Lewes. *Inoceramus*, *Pecten*, and usual shells of the White Chalk and Chalk Marl.

Ludlow. *Pentamerus*, *Spirifera*, &c. and other Silurian shells.

Lyme Regis. Lias. *Plagiostoma*, *Gryphæa*, *Trochus*.

Malton. Beautiful shells of the Oolite.

Matlock, Derbyshire. The mountain limestone in the vicinity abounds in the characteristic shells *Leptæna*, *Spirifer*, &c.

Minchinhampton. Numerous shells of the Great Oolite.

Osmington, near Weymouth. Purbeck; fresh-water and marine shells: Oolite; *Trigonia*, *Gervillia*, *Perna*, *Pholadomya*, and many other genera.

Portland, Isle of. Oolite. In the stone-quarries immense numbers of the genera *Trigonia*, *Venus*, *Ostrea*, *Pecten*, &c.

Pluckley, Kent. Lower Greensand. *Trigoniæ*, *Terebratulæ*, &c.

Radipole, near Weymouth. *Trigonia*, *Pholadomya*, &c. in Oxford Clay.

Sandgate, near Margate. In the Greensand, the usual shells.

Scarborough. In the cliffs along the shore, a profusion of Oolitic and Liassic shells.

Selbourn, Hants. In the firestone, *Ostrea carinata* and other characteristic shells.

Shalfleet, Isle of Wight. In tertiary fresh-water limestone, shells of various genera, as *Bulimus*, *Helix*, *Planorbis*, &c.

Shanklin Chine. Greensand. In the cliffs along the shore, *Terebratulæ*, *Gryphites*, *Gervilliæ*, and many other shells.

Sharnbrook, Bedfordshire. The usual shells of the Cornbrash and Lower Oolite.

Sheppey, Isle of. Eocene. London Clay shells, in abundance.

South Petherton, Somerset. *Terebratulæ*, *Pholadomyæ*, *Ostreæ*, *Pleurotomariæ*, &c. of the Marlstone.

Stamford, Lincolnshire. Lower Oolite. Univalves and bivalves in profusion.

Stonesfield, Oxfordshire. *Trigoniæ* and other shells of the Lower Oolite.

Stubbington Cliff, near Portsmouth. Eocene shells.

Swanage. In the quarries in the vicinity, the prevailing fresh-water shells of the Purbeck limestone.

Swindon, Wilts. Oolite. The Portland limestone abounds in the usual shells of that deposit. *Trigoniæ*, *Gervilliæ*, &c.

Taunton, Somersetshire, (Pickeridge Hill, &c.) *Lima*, *Pecten*, and other Liassic shells.

Tisbury, Wilts. Beautiful *Trigoniæ*, and other shells of the Portland Oolite.

Vincent's, St., near Clifton. The rocks abound in the usual shells of the mountain limestone.

Walton, Essex. Shells of the Crag, in great variety.

Weymouth. The Oxford Clay and other strata in the vicinity contain great variety of fossil shells.

Whitecliff Bay, Isle of Wight. Eocene. Marine and fresh-water shells.

Worthing. The chalk quarries in the neighbourhood are remarkably prolific in the usual species; and yield *Sphærulites*.

NOTE.—A comprehensive list of the localities for *Lower Palæozoic* shells, &c. is given by Prof. M'Coy in the second Fasciculus of the "British Palæozoic Fossils;" and in the little "Stratigraphical List," published by Mr. Tennant, reference is carefully made to the localities for the fossils of every formation.

END OF VOL. I.

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